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HANDBOOK  
OF  
POTATO DISEASES  
IN  
AUSTRALIA.

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UNDER SURFACE OF BLIGHTED POTATO LEAF, WITH BROWN  
BLOTCHES AND DENSE WHITE MOULD

DEPARTMENT OF AGRICULTURE, VICTORIA.

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HANDBOOK

OF

FUNGUS DISEASES

OF THE

POTATO IN AUSTRALIA

AND THEIR

TREATMENT.

BY

D. McALPINE,

*Government Vegetable Pathologist.*

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WITH 158 FIGURES.

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## PREFACE.

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It is not to be imagined that potatoes in Australia are more subject to disease than in other parts of the world, for only those diseases are to be found which are more or less common wherever the potato is cultivated, and, as a matter of fact, there are several very serious diseases which have not yet reached us.

Under the heading of "scab" it is shown that some of the worst diseases with which the grower has to contend in Britain and elsewhere are not known here, simply because the fungi causing them have not been introduced, and with a Quarantine Act in existence they are not likely to be.

But while this is so, there are quite enough, including the Potato Blight, to call for the most careful attention on the part of the grower, and the study of the most improved methods of treatment. Besides, the rigid system of inspection carried out under the Vegetation Diseases Act has brought home to the grower, in the most convincing manner, the existence of diseases which were previously regarded by him as of little consequence, and there is a natural desire on his part to know something of their nature and how they are caused, in order to avoid them, if possible. He soon discovers that, although he may have been growing potatoes for a lifetime, and knows their habits of growth and the proper mode of cultivation, so as to ensure a good crop, yet when disease attacks them the superficial indications do not enable him to get to the bottom of it, and he is confronted with problems foreign to his experience. Experiments in the laboratory, as well as in the field, are necessary to find out their true nature, and it is the aim of this Handbook to educate the grower, so that he may recognise those diseases which are caused by fungi, and from a study of their peculiarities to adopt such precautions as will either prevent, or at least minimize, their ravages.

Every disease treated of has been personally investigated, and my assistant, Mr. C. C. Brittlebank, has rendered valuable help throughout. Mr. Seymour, Potato Expert, has also willingly given me the benefit of his wide experience in all matters relating to the cultivation of the potato.

Melbourne, September, 1911.



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## INTRODUCTORY.

Potatoes are noted for their great liability to disease, suffering more from the ravages of fungi than any other crop, and this is largely owing to the fact that they are propagated from tubers, which are just swollen portions of underground branches of the stem. Portions of the parent plant, in the form of tubers or cuttings, are planted year after year, so that any inherent weakness in the original is transmitted to the offspring, and thus, without a process of selection, deterioration is sure to occur, sooner or later. When the tubers are raised from seed, as is occasionally done, and a good selection made from the seedlings, they are said to be less liable to disease, at least for a number of years. This tendency to disease is unwittingly encouraged, owing to the very laudable desire on the part of the grower to choose such varieties for seed-potatoes as yield a large-sized, thin-skinned, mealy potato, thus making it more of an artificial product and an easier prey to the inroads of fungi.

It has also to be remembered that potatoes have been a long time under cultivation, from the period of the discovery of America, where cultivation was practised, until it became general in Britain about the beginning of the eighteenth century. They have always been subject to more or less partial failure, and even before the potato blight appeared, the scab and the dry rot were common among them. Now that the potato blight has been discovered in all the States, Australia possesses most of the principal diseases known in other countries.

There is often a complication of diseases in the potato which renders investigation more difficult. Thus the Early Blight and Wet Rot may be associated with the so-called Late Blight, and the *Rhizoctonia* disease and Eel-worm as well, so that it is not always easy to determine which is the principal cause of the trouble. There are also a number of minor ailments which in the aggregate may become serious.

The potato industry is such an important one that whatever tends to improve it is worthy of encouragement, and undoubtedly the study of the diseases to which the potato crop is subject will have good results. I am indebted to the Commonwealth Statistician, Mr. G. H. Knibbs, for the information contained in the following table, which shows the total annual value of the potato industry to the Commonwealth to be over one and a half million pounds sterling, of which Victoria contributed over two-fifths of the whole. Victoria is also the principal potato-growing State as regards area, and is thus vitally interested in the prevention of disease, and if growers would only take the necessary precautions, the average yield per acre might be considerably increased.

TABLE I.—COMMONWEALTH AREA UNDER POTATOES, PRODUCE, AVERAGE YIELD, AND VALUE.

State.	Area.		Yield.		Average Yield per Acre.		Value of Crop.		Area.
	Acres.	Acres.	Tons.	Tons.	Tons.	Tons.	£	£	
	1908-9.	1909-10.	1908-9.	1909-10.	1908-9.	1909-10.	1908-9.	1909-10.	1910-11.
New South Wales	26,301	35,725	71,794	100,143	2·73	2·80	372,304	461,130	44,437
Victoria ..	47,903	62,390	152,840	174,970	3·19	2·80	580,792	673,635	62,904
Queensland ..	6,227	7,708	11,550	13,544	1·85	1·76	92,400	94,808	8,326
South Australia..	8,069	8,131	21,553	18,569	2·67	2·28	106,542	102,129	7,472
Western Australia	2,026	1,741	6,695	5,948	3·0	3·42	53,500	59,480	1,791
Tasmania ..	35,159	21,375	121,605	73,862	3·46	3·46	425,600	246,206	26,230
Total Commonwealth ..	125,685	137,070	386,037	387,036	3·07	2·82	1,631,138	1,637,388	151,160

The remarkable falling-off in the area under cultivation in Tasmania during 1909-10 is chiefly due to the widespread prevalence of potato blight, and to recover lost ground it will be necessary to adopt all the modern methods known for coping with it. If we take the United Kingdom for comparison, in 1908, the acreage under potatoes was 1,149,000, and the yield 7,117,000 tons, showing that even with potato blight to contend against, there is still a large area devoted to potatoes, and the average yield is 6.19 tons per acre.

In Victoria the area under potatoes for 1910-11 is practically the same as the preceding year, but the produce is 163,312 tons, as compared with 174,970 tons. This gives an average yield per acre of 2.60 tons, so that notwithstanding the prevalence of blight there is not a great difference in the average yield, owing to the splendid season for growth.

As regards the loss incurred through any particular disease, it is not easy to determine, since there may be several present at the same time, but the potato blight is so distinct in its effects that more or less reliable estimates have been made concerning it. In the United States, it is reckoned that there is an annual loss from the disease of £7,500,000, and in New Zealand, for 1905, it was estimated at nearly £200,000. When it is remembered that tomatoes have been found affected with the same blight in Victoria, New South Wales, and Queensland, it is evident how widespread the loss may become if prompt measures are not taken.

In Victoria, it is a moderate estimate, derived from my own observations, and those of the various potato inspectors, that one-half of the crop, or 50 per cent., was destroyed by the blight during 1910-11. The season was a very favorable one for growth, and many of the crops yielded well, in spite of the blight.

In the following account of the diseases of the potato a full description has been given of those which have actually been found in the Commonwealth. It is so customary for those who pose as authorities on the subject here to speak of diseases which have been found in America or elsewhere as being Australian, even although they have never investigated or microscopically examined a single disease, that it has become necessary to definitely define the diseases actually existing.

There is a widespread desire on the part of growers to know more about the diseases of the potato, for the ignorance of the past can no longer be tolerated, since there is a rigid system of inspection to prevent diseased tubers passing from one State to another. It is only a natural result of this inspection that the different Departments of Agriculture should place in the hands of growers the necessary information and the most practical methods for preventing such diseases which entail a large annual loss to the industry. It is now well known that many of these fungus diseases are carried over from season to season by means of the "sets" planted, and that if only healthy seed was used, and planted in soil free from the fungus, as in the case of "Dry Rot" and "Wet Rot," the disease would not appear. It becomes a question of practical importance, therefore, to determine when the seed is perfectly healthy, for the germs of the disease may lurk within, even although the tuber may appear quite sound externally.

We must be on our guard against repeating the mistakes of older potato-growing countries. In Ireland, Dr. Johnson, who investigates the diseases of plants for the Department of Agriculture, has visited districts in the west, where potatoes have followed potatoes for more than fifty years, and, consequently, disease is rampant. "I am thoroughly convinced," he writes, "that the prevalence of yellow blight and of scab in the potato crop in the west, not to mention the ordinary leaf-blight, is largely due to the planting

of diseased seed. It is the exception to see healthy tubers. Nearly every tuber I have examined showed some sign of disease." And Count Arnim, in Germany, who is known as a skilled producer of potato varieties, and has a research laboratory on his property, in his pamphlet on *Europe's Potato Industry in Danger*, estimates the loss in Germany, in the potato crop for 1908, through planting the diseased seed-tubers of 1907, will be at least £30,000,000.

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## I.—POTATO BLIGHT OR LATE BLIGHT.

*(Phytophthora infestans de Bary).*

## HISTORICAL.

This disease has been discovered in all the States of the Commonwealth, and was originally introduced in the seed potatoes. Just when it was first introduced into the various States it is impossible to say, but it has been recorded for New South Wales as far back as 1846, the year after the severe epidemic in Ireland of 1845. The original home of the potato is in South America, whence it was brought to Europe in the sixteenth century, and this disease occurs on the wild form in Chili. No doubt it has existed in the potato since its first introduction, and although the early accounts of it are rather obscure, yet in 1840 it was very prevalent in France and Germany. In 1844, it assumed the character of an epidemic in Canada and St. Helena, and, in 1845, the serious outbreak occurred which spread over Western Europe and the United States. Berkeley, in his article entitled "Observations, Botanical and Physiological, on the Potato Murrain," in the first volume of the *Journal of the Horticultural Society* (1846), begins as follows:—"Few subjects have attracted more attention, or have been more variously canvassed, than the mould with which potatoes have been almost universally visited during the autumn of 1845. The press has teemed with notices the most contradictory; the attention of scientific men in every direction has been engaged by it; and three, at least, of the principal Governments of Europe have issued commissions to examine into its etiology, and to discover, if possible, a remedy." Not only was it bad in 1845, but it increased in 1846, then assumed a milder form in 1847, and returned with greater virulence in 1848. Because it was particularly bad in Ireland, where potatoes are so extensively grown, the disease received the name of Irish Blight, although in Tasmania at the present time it is generally known by farmers as "Brown Rust." The latter name, although expressive, is an unfortunate one, for the potato-grower in many cases can hardly be convinced that this brown, dry decay immediately beneath the skin of the potato (Fig. 2) has any connexion with the soft-rotting, foul-smelling symptoms which he invariably associates with the blight. He is not aware that the fungus of potato blight only produces this brown decay and prepares the way for scavengers, such as bacteria, which extend the decay thus set up, and give rise to the slushy rot and the disagreeable smell. Affected potatoes are often quite firm when dug, but the sunken skin and the browning of the tissue immediately beneath, generally indicate a tuber with the spawn of the fungus within.

On the other hand, I have had diseased potatoes just as bad as anything I have seen in Ireland or Scotland, and it is just because the conditions are not always favorable in our drier climate to the development and spread of these ubiquitous bacteria that the final stages of decay are not always reached.

It is interesting to recall that in the neighbouring Dominion of New Zealand there was an outbreak in 1893, but it was of such an apparently harmless character that the growers took no special notice of it, as they attributed the blackening of the leaves to frost, and it was only eleven years afterwards that the disease became so pronounced as to receive official recognition. History repeats itself, for the self-same reason was assigned for the blackening of the leaves in the Western District in 1910, but the examination of the leaves, stems, and tubers revealed the presence of the potato blight fungus.



The recent history of the discovery of potato blight in the different States may now be given, but it is highly probable that it existed in Australia before 1909, although undetected. The already wide distribution of the disease in some cases, and the explicit statement of its occurrence in others, bear out this view. Thus, as far back as 1846, the year after the terrible epidemic in Ireland, Joseph Phipps Townsend, in his "Rambles and Observations in New South Wales," dated October, 1848, remarks:—"Very fine black potatoes are also grown on the coast; but I observed in the local papers that the potato disease made its appearance in the colony in August, 1846." In Queensland, too, Professor Shelton had determined it at least as early as 1892, for, in a Report issued by the British Board of Agriculture, in April, 1892, Queensland is the only Australian State in which the disease is mentioned, as follows:—"Instances have occurred of *Peronospora infestans* affecting the haulm, but the effect on the crop being slight, necessitated no precautions or preventive steps being taken." So that, in two of the States at least, the disease was re-discovered, and probably also in the others, although there is no definite account of it.

In 1909, it was determined in each of the States, after an examination of the fungus producing it, and the order of its discovery in the respective States is here given. It was first discovered or announced in Queensland by the Government Entomologist and Vegetable Pathologist on 19th May; in Tasmania, on 19th July; in Victoria, 23rd July; in South Australia, 29th July; in New South Wales, 11th August; and at Guildford, in Western Australia, on 31st August.

#### SYMPTOMS OF THE DISEASE.

The signs or symptoms of the disease may be seen either on the potato-plant above ground, or in the tubers underground. As soon as the leaves appear, they may begin to show signs of it. Instead of the green, healthy-looking leaf, the young leaves become pale in colour, and of a yellowish-green. Then there may appear, generally towards the edges and tips of the leaves, irregular brown patches, or blotches, because the moisture collects and remains longer at these spots, and surrounding these, on the under surface, there is a delicate white mould just visible to the naked eye. There may be brown patches due to other causes, but the white or ashy-grey mould in addition, either on or around the decaying portions, is a sure sign of the blight. (Frontispiece).

More or less rapidly, according to the state of the weather, the blotches spread until the entire leaf may turn black and rotten, giving forth an offensive odour, or the leaf may simply show the brown blotches and wither up. If the weather is favorable, the disease spreads to the stems, which finally rot, like the leaves. This premature rotting of the green portions of the potato-plants affects the growth of the tubers underground, if they are not already fully formed, and the disease may reach them, although some of the tubers may remain sound, while others are affected. If diseased potatoes are examined, they usually show a depression of the skin here and there, and when cut across the flesh is brown, at first immediately beneath the skin, and this browning may extend more or less inward, as shown in Fig. 2.

The rot may not penetrate deeply at first, but ultimately the entire tuber may become a putrid, evil-smelling mass. Under the conditions of heat and moisture, which often prevail in Australia, the rot may not go beyond the brown stage at first, when it is known as "Brown Rust," and it is only when

this is followed up by microbes or bacteria that soft rot sets in, and the offensive odour associated with the disease asserts itself. If the soil is comparatively dry, then the dry rot or "Brown Rust" results, but if wet, then the decay of the tubers is of the wet, soft, badly-smelling type.

#### RELATION OF THE FUNGUS TO THE DISEASE.

It is so ingrained in the minds of many growers that the weather is the primary cause of this disease that it is necessary to convince them of the connexion between the fungus and the disease. In all the numerous determinations of this disease which it has been necessary for me to make, in order to settle the individual farms affected, I have invariably found associated with it the same fungus, and this self-same fungus occurred wherever the disease was found, whether in Britain or America, New Zealand or Australia. But the relation of this fungus to the disease might be that of an after-effect, the fungus following rather than causing the disease. To prove the latter, it will be necessary to produce the disease in healthy potatoes by means of the fungus, and this has been done both by the spawn and spores inside the tuber, as well as by the spores on the outside of it.

#### INFECTION OF TUBERS WITH UNBROKEN SKIN.

A clean, healthy Carman potato was kept moist, and surrounded with slices of a diseased potato. In sixteen days the disease appeared in the originally healthy potato by mere contact with the diseased, while similar clean Carman potatoes, kept by themselves under similar conditions, showed no trace of it.

But it is not necessary that there should be direct contact, for the cases containing the spores or propagating bodies may be carried through the air and produce the same result. Some spores taken from the potato shown in the Plate I. were placed on the moist surface of a clean Carman potato and kept damp. At the end of sixteen days the clean potato was affected, and even showed tufts of the fungus on the surface. Massee has stated that he did not succeed in infecting young tubers with spores, even when placed under very favorable conditions for doing so, but I have had no difficulty in producing infection under ordinary moist conditions, and the soundness of the potato, to begin with, was placed beyond doubt.

#### INFECTION OF TUBERS WITH BROKEN SKIN.

Potatoes were also infected beneath the skin, both with the mycelium and spores, just as would happen when the skin was bruised from any cause, and the disease soon appeared. Clean potatoes were thus infected with minute fragments of mycelium, about the size of a pin's head, at various points, and similarly with spores, and the result was always the same—infection took place, and the disease quickly spread. This mode of infection was much more certain than on the unbroken skin. As a typical example of a clean potato infected beneath the skin in several places by fresh sporangia, I will give the history of one which is represented in Plate xxxv., and the tuber was of a good size, being six inches in length. It was infected on 8th July, and, after five days, there was external evidence of the disease in the darker colour of the skin surrounding the points of infection. In the course of a fortnight the infection had spread beneath the skin to the extent of an inch and a half, and in three weeks the entire surface of the potato was darker, and somewhat wrinkled, from the internal mycelium having become continuous immediately beneath the skin. It had also penetrated to a considerable distance inside

the tuber, so much so that on the twenty-second day after infection a slice cut lengthwise near the middle of the potato showed the browning of the tissue, as in Fig. 116. The potato was simply kept on a shelf in the laboratory, and even under these dry conditions the disease developed vigorously and rapidly.

It can be readily understood how clean potatoes in a pit, if infected by spores on the broken skin, from adjoining diseased potatoes, or by contact with the mycelium, would rapidly succumb to the disease.

Under moist conditions the sporangia were naturally formed on the surface of the potato, as seen in the Snowflake, picked up in the field, and represented in Fig. 1, as well as in several small boxes of potatoes sent over from Tasmania, freshly dug, and closely packed. It was not at all uncommon to find potatoes taken from damp soil with the fructification on the surface.

#### INFECTION OF POTATO TOPS ONLY.

Experiments were carried out to see the effect produced by infecting the tops or haulm of a growing healthy potato. A self-sown potato, when about one foot high, was infected on 22nd August with the spores of potato blight. The mode of infecting was by means of spores taken fresh from diseased potatoes, shaken up in a small phial of water, and a drop placed upon the centre shoots of the potato plant, as well as on the under surface of several leaves. Three days after infection, irregular dark green patches were observed where the drops had been placed. These patches rapidly became dark brown to black, and on mounting a scraping from these patches the fructification of the fungus was obtained in abundance.

The tips of the plant had now turned black and dry, although abundantly supplied with water, and the upper parts of the stem as well as the leaf-stalks were semi-transparent. A week afterwards, or ten days from the time of infection, several diseased patches appeared on the stem about an inch from the ground, and also on the lower leaves, showing either that the mycelium of the fungus had travelled downwards, or that the falling spores from the upper leaves had spread the infection.

The disease now spread rapidly underground, and thirteen days after infection the entire portion of the plant above ground was black and rotten. On removing the soil, the underground portion of the stem, even to the very tip, was also seen to be quite black, soft, and rotten. The tubers were then removed, and appeared to be quite healthy, although few in number and small in size. They were kept in a closed jar for further observation, and on being carefully tested in March, 1911, showed no sign of disease. The eight tubers, varying in size from hazel nuts to walnuts, sprouted, and were planted in June, 1911. The healthy potatoes growing alongside remained quite clean.

This experiment shows that when infection begins in the "tops" the mycelium may pass down the stem, even to the underground portion, and although it did not reach the tubers in this particular instance, yet if left a little longer in the ground, it would in all probability have done so.

#### INFECTION OF TUBERS ONLY, FROM PLANTING DISEASED "SETS."

The general opinion held in other countries is that the spores reach the tubers through the soil after falling from the foliage. The foliage is first visibly affected with the blight, and generally the leaves are almost all destroyed before many tubers are found to be diseased. But how is the foliage infected? Some are candid enough to admit that it must come from diseased tubers at the beginning of the season, while others still rely upon some occult source.



We have shown that tubers may be infected by spores falling upon them, but in a comparatively dry season, accompanied by heat, the sporangia are not formed above ground, and yet the tubers are diseased, showing that the mycelium originating from a diseased "set" must enter the tubers directly, without having invaded the portions above ground.

I have met with plenty of such cases in the potato field which are convincing enough to the actual observer, but potatoes have been planted on the surface of the ground under straw, so as to scientifically prove direct infection.

#### LIFE HISTORY OF THE FUNGUS CAUSING THE DISEASE.

This may be briefly given, and easily followed, by referring to the illustrations taken from photographs. The fungus is itself a plant; or, as it is called, a parasite, because it preys upon the food contained in the living potato-plant. We have also to distinguish in the fungus, as in any other plant, two principal parts—the one which feeds and collects the nourishment, and the other which propagates the fungus. The feeding portion is inside the leaf, stem, or tuber, and the breeding portion is on the outside, except in the case of the tomato, where it may also be inside.

These two parts are seen in the section of diseased leaf shown in Fig. 5. The numerous threads of the fungus inside the leaf twist and turn among the cells of the plant, and form what is known as the spawn or *mycelium*, while the slender threads on the under surface of the leaf bearing oval bodies, form the *fructification*.

The mycelium causes the discolouration and death of the cells with which it comes in contact, or into which it penetrates. In the leaves it produces the brown spots, and in the tubers, as shown in Fig. 8, it surrounds the starch-cells, drawing nourishment from the starch contained in them, and, at the same time, causing their decay and death. It probably also preys upon the other contents of the cells. If a small piece of the brown portion of the tuber in Fig. 2 is examined under the microscope, the spawn of the fungus is seen spreading in all directions among the cells. The mycelium may remain dormant in the tissues if the necessary heat and moisture are not supplied, but, usually, after it has exhausted the nourishment at a particular spot, it gives rise to the fructification. On the under surface of the leaves it forms the downy mould (*Frontispiece*), and tufts of the same mould appear on the surface of the tuber, as shown in Fig. 1.

The fructification consists of long branching threads standing out from the surface, and at the end of each branch there is an egg-shaped body, which is known as a spore-case or *sporangium*, because it contains the spores of the fungus, which are equivalent to seeds as far as propagation is concerned.

This particular fungus, however, does not rest content with producing one spore-case at the end of each branch, but it grows beyond this and produces another and still another, until there are quite a number, as shown in Figs. 9, 12, where each swelling on the branch indicates the spot from which a spore-case has fallen. When it is realized that as many as nine spore-cases may be produced on one branch, and that the portion of the leaf, shown in Fig. 5, only actually measures one-sixtieth of an inch, it can be imagined what myriads of spore-cases may be produced by a single potato-plant, and when it is known that the sporangia are so small that it takes 800 of them end to end to measure an inch, it can be understood how readily they are blown about by the slightest breath of wind to neighbouring potato-plants.

If the plant is moist with dew or rain the contents of the detached spore-case break up into from six to twelve portions in a very short time, and each of these pieces squeezes out through an opening at the top of the case and swims about on the moist leaf, or tuber, by means of two cilia, or swimming organs (Figs. 13, 15). After eight to ten minutes, or a quarter of an hour, these swimming spores settle down and soon begin to sprout, as shown in Fig. 16. The germ-tube is able to pierce the skin of the leaf or the potato, and once inside, this slender thread grows and multiplies at the expense of the food contained in the leaf or tuber, and soon causes the cells to turn brown, as in Fig. 2. Since the spawn of the fungus, under moist conditions, may produce spore-cases in fifteen hours, and in the case of the tomato in seven and one-third hours, it is not to be wondered at that in moist, muggy weather the disease spreads from plant to plant with amazing rapidity. It will also be understood why moisture is necessary, for under dry conditions the swimming spores are not produced, and even if formed, if a dry spell came they would soon dry up and perish. Hence also the common notion that mist causes the disease. But even if the amount of moisture is limited the fungus can still adapt itself to the situation. Under these conditions the spore-case does not divide into spores, but it sprouts direct, as shown in Fig. 17, and it can even play a waiting game, if necessary, for it may produce another body like itself, as in Fig. 19 (to right), ready to reproduce the fungus, if favorable conditions are not too long delayed.

Such is the wonderful life-history of this remarkable fungus, but how it survives from season to season remains still to be told.

In briefly recounting the life-history of this fungus, as made out by the microscope, and photographed, I have avoided technical terms as much as possible, but in doing so there is a danger of not being quite explicit, and this is more particularly the case in dealing with what is popularly called the fructification of the fungus. The oval bodies which produce the spores are known as sporangia, or spore-cases, and since the spores move about in the water, like minute animals, they are generally called zoospores, or swarm-spores. But in certain cases, where there is not a plentiful supply of moisture, the bodies, which usually break up into spores, may germinate directly and penetrate the tissues of the potato. They are then known as conidia. The reproductive bodies are, therefore, either sporangia or conidia, but for convenience I often just speak of them as if there was but one essential element—the spore.

#### WINTERING OF THE MYCELIUM.

Since the spores are the only reproductive bodies known, and as they do not long retain their power of germination, succumbing very rapidly in dry weather, it is evident that there must be some other means of carrying over the fungus from season to season. In some of the fungi related to that which causes the potato blight, there is a winter or resting spore, which serves the purpose, but in the absence of that in this case, there is a substitute for it in the mycelium which winters in the seed. The widespread and simultaneous outbreaks of the disease can thus be readily accounted for, when it arises from the "seed" potatoes, and is only partially dependent on the spores being blown from plant to plant. The mycelium in the seed grows with the growth of the plant, but only reaches extensive development in wet, muggy weather, such conditions being favorable for its development.

It is well known that in some seasons diseased potatoes may produce a fairly sound crop, because the conditions which enabled the potatoes to make good growth were inimical to the excessive development of the mycelium in the tuber. A good illustration of this is given by Mr. Massee, in



connexion with his experiments on the wintering mycelium. Tubers showing the rusty stains characteristic of the disease were sown in pots. They were grown in a cool, well-lighted, dry house, and showed no trace of disease at the end of two months. One of the plants was removed to a warm house, and placed under a bell-jar, and it was killed by the fungus in nine days. A fortnight later another plant was removed to the same place, and within a week it was covered by the fungus. The third plant continued growing in the cool house for thirteen weeks, and there was no *obvious* disease about it, but of course it was latent there, ready to develop as soon as the conditions were favorable.

It used to be considered, when the wintering of the mycelium in the tuber was not clearly recognised, that the spores were carried immense distances, because sudden outbreaks occurred simultaneously over a wide area, but from what is now known concerning the nature of the spores, and the duration of their life, the evidence is in favour of the spread of the disease over large areas through the tubers. Massee has stated this view in a very emphatic way:—“Potato disease is now present in every part of the world where the potato is cultivated, and we have no hesitation in saying that the disease has been conveyed from one place to another by means of hybernating mycelium in the tubers, and not by means of spores.”

I have just received, through the courtesy of Dr. Pethybridge, a very suggestive paper read by him before the Royal Dublin Society, and published in March, 1911, entitled, “Considerations and Experiments on the Supposed Infection of the Potato Crop with the Blight Fungus (*Phytophthora infestans*) by Means of Mycelium derived directly from the Planted Tubers.” He strongly opposes the theory of infection from a dormant mycelium in the seed potatoes, and, consequently, cannot account for the *first* appearance of the disease in the new season’s crop. “In one fundamental point, in particular, we are still almost completely in the dark, and that is the manner in which the potato-plants first become infected each succeeding season.” His opposition to this view, which is the most reasonable way of accounting for the fresh distribution of the disease each year, is based upon the supposed fact that diseased tubers do not produce diseased plants. He gives a summary of what happens to diseased tubers as follows:—

- (1) They die before planting time;
- (2) They die, if planted in ground, without producing any over-ground stalks;
- (3) They produce small stalks above ground, which soon die, owing to direct infection with the fungus from the parent tuber;
- (4) They produce healthy plants, which, provided there be no opportunity during the season of becoming infected by aerially-borne “spores,” remain free from the disease.

This reasoning seems to have all the cogency of a mathematical proposition, but, unfortunately, it does not take into account all the facts. The weakness of the whole position, to my mind, is this, that the behaviour of a few potatoes, healthy or diseased, when planted in pots, is to be taken as an absolute, and not a relative, indication of what takes place in the field. The point at issue is, whether diseased “sets” produce diseased crops or not. If we take a broad and general view of the subject, without confining ourselves to the results of a few pot experiments, there are some outstanding facts worthy of consideration. First of all, if we ask ourselves the question, How was the disease introduced into Australia, or, for that matter, into Ireland, from the original home of the potato? The only reasonable reply is, that it was introduced in the potato itself, by means of the spawn or mycelium, which we know to be very tenacious of life.

Then again, when a fair-sized plot of potatoes was planted with partially-diseased tubers in virgin soil, in a locality surrounded by natural barriers, and far distant from any source of infection, the resulting crop was largely diseased, from 70 to 90 per cent. being affected, and not a single plant escaping. Now, even allowing for a considerable amount of infection from the spores produced on the field, the diseased tubers planted must have formed the starting point; and even Dr. Pethybridge himself has to admit that infection by means of diseased tubers does occur, although he minimizes it as much as possible, for he says, "If we except the few diseased plants from diseased tubers, which do undoubtedly occasionally occur, but which can scarcely be regarded as being part of the general crop."

We have opportunities in Australia of planting potatoes for the first time in districts quite isolated from any outside sources of infection, and yet the disease occurs there. No amount of special pleading can get over the origination of the disease from the tuber, and so William G. Smith philosophically, if not scientifically, winds up his consideration of this disease by saying, "How the disease reaches the green tops of next season's crop is not clearly known, but it must come from diseased tubers."

I had a splendid illustration of this in Gippsland, where a grower planted seven acres of potatoes for the first time in virgin land, and far removed from any other potato-growing centres, having secured his seed from a district reputed to be free from blight. The plants grew healthily, but, after flowering, the tops and tubers became badly affected. I was so convinced, from the surroundings, that the disease had been carried in the seed potatoes, that I asked the name of the grower in a distant part of Victoria who had supplied the seed, and, on visiting that particular farm, the disease was found there, although that particular district had hitherto been considered clean.

Every potato planted does not require to be diseased in order to explain the general spread of the blight, for once the disease has started in a paddock, the spores are readily carried by the wind to neighbouring plants, until the whole field is soon involved.

Further, it is hardly realized how long the mycelium may remain dormant and still infect the tubers when favorable conditions arise. I had some specimens of diseased potatoes sent from Killarney, Victoria, on 24th October, 1910, and there was no doubt of their being infected, for the fructification of the Irish Blight fungus actually appeared on the surface of the young tubers. One of these was immediately placed under a bell-jar, and at the end of four months (24th February, 1911) it had become dry and shrivelled, and quite hard. The potato was certainly as dead as a mummy, but a small portion of it was inserted beneath the skin of a perfectly healthy Carman No. 1 potato, which was placed under a bell-jar, and not even kept moist. A similar healthy Carman potato was kept as a check, under the same conditions, and no sign of disease appeared in it. The disease soon began to show itself in the infected potato, starting from the point of infection, and at the end of May, the entire potato had become diseased. That this disease was Irish Blight was not only evident from the appearance, but a slice taken and kept moist under a bell-jar developed the fructification in forty hours. Dr. Pethybridge asks, "How could *Phytophthora*, if present internally, have succeeded in carrying on an existence for over three months without exhibiting some signs of its presence?" Here is an actual case where the mycelium remained in the tuber without showing any signs of its existence, and yet, at the end of four months, it was capable of infecting a healthy potato.

The pot experiments carried out by Dr. Pethybridge were on similar lines to those of Massee, with the addition of control plants, but the results were diametrically opposite: Out of three healthy "sets" planted in

pots, and placed in a warm greenhouse, all grew, and remained perfectly healthy, while of three diseased "sets," similarly treated, one rotted away, and the two others produced perfectly healthy plants. Again, out of nine healthy "sets" planted in pots, and placed in a cool greenhouse, all grew at first and produced healthy plants, but ultimately the blight appeared on all the plants but one, which remained healthy. Of nine diseased "sets," planted like the preceding, three completely rotted in the soil, and all the rest of the plants, with the exception of one, became diseased.

The two healthy plants, one derived from a healthy and the other from a diseased "set," were placed in the warm greenhouse, and covered with a bell-jar, but no signs of blight appeared on them. "The result of my experiment," as stated by Dr. Pethybridge, "is in agreement with those of many previous workers, which are in the main to the effect that tubers affected with *Phytophthora* produce healthy plants." But for an explanation of the infection of the healthy plants it is necessary to assume its origin from a diseased "set." "Although absolute proof is lacking, it seems practically certain that the plants whose foliage became diseased must have become infected by means of 'spores' from the single diseased sprout sent above ground by one of the diseased 'sets.'"

That the results should be different in a few pot experiments is not to be wondered at, but whenever field experiments are undertaken with diseased "sets," and the weather favorable, the produce is invariably diseased.

The objections raised to the infection of potato plants at the beginning of the season by the mycelium or spawn of the fungus may be briefly stated and answered.

1. How could the internal mycelium pass from the tuber through the stalk to the leaves and remain dormant for months, without exhibiting some signs of its presence?

In this case the rapidly-growing potato-plant is able to provide for the wants of the fungus, as well as its own, but when flowering time comes along, and this is the usual period when the fructification of the fungus begins to appear on the leaves, then the nutritive material is required for its own needs, but the fungus steps in, appropriating the nourishment, and asserts itself by producing its fructification, and more or less rapidly destroying the various portions of the plant.

2. How are the beneficial results of spraying to be accounted for, if there is a dormant internal mycelium?

This is generally considered to be an insuperable objection to the idea of infection of the plant by means of a diseased "set," and no doubt it seems at first sight a great stumbling-block in the acceptance of this view, but, rightly understood, I consider it to be the strongest argument in its favour. Dr. Pethybridge writes:—"If this theory [dormant internal mycelium] is correct, it seems almost impossible to explain the undeniably beneficial results accruing from spraying the crop with Bordeaux or Burgundy mixture." It is the object of spraying to save the plant from infection, and if the fungus has already gained an entrance into the tissues, it is beyond the reach of spraying.

But it is well known that the results of spraying are very variable, and, in my opinion, the variable results obtained from spraying are largely due to the two different modes of infection. If a large proportion of the plants are infected from the tuber, owing to careless selection of seed, then spraying will not have much effect, but if the infection is due to wind-borne spores, then, if spraying is done at the right time, before the blight has attacked the plants, then it may prove very successful. In fact, there is no reason why



it should not be completely successful, if it has simply to protect the plant against wind-borne spores, and my contention is that it is *because* the fungus is inside, derived from the tuber, that spraying is sometimes attended with poor results. For success in spraying a careful selection of seed is a great help. Any one who has studied the blight in the field must have noticed, in its early stages, how it often occurs in patches, although it may soon become continuous, and in these patches you can sometimes tell the very plant from which it spread. A very striking case was brought under my notice. There was a patch in the paddock where the disease was specially bad, and, on examining that patch, there was one plant, towards the centre, much more collapsed and decayed than the others. On digging it up, it was found that the four or five good-sized tubers were badly diseased, while the tubers of surrounding plants were still apparently healthy. The one plant had been infected from the "seed," and the spores had been carried from this as a centre to neighbouring plants.

3. Why are the tubers infected by falling spores from the leaf, and not by the internal mycelium passing along the underground branches and attacking the new crop?

As a matter of fact, the new tubers are infected in both ways, and the diseased area may be found spreading from the stalk end or from any portion of the surface at first, and always immediately beneath the skin. I have traced the entrance of the mycelium through the stalk to the young tuber, and I am endeavouring to demonstrate, in a practical fashion, that this is the way in which each tuber is infected when spores falling from the leaf are excluded.

To settle the question of direct infection of the tubers from the parent plant by the mycelium, I have planted some diseased potatoes on the surface of the soil under straw. The object is to watch the tubers while growing, and see if the mycelium passes direct to them.

The soil is reduced to a fine tilth, and the diseased potatoes are planted firmly in the ground until half covered, then a coating of straw, about one foot deep, is placed over them.

4. "Another strong argument against the acceptance of this theory is that, according to it, the attack of the stalks must proceed from below upwards, whereas the exact contrary is what is actually found to take place in the field."

What takes place in the field is this, based upon an examination of the young shoots and tubers at different stages of growth. When the tuber is planted, and the heat and moisture favorable to it, it begins to sprout, and the mycelium also becomes active, growing into the shoot, as indicated by the presence of the mycelium there. Then the fungus may grow so luxuriantly, if the weather is moist and muggy, which renders the young tissues of the potato exceedingly soft, that it completely overcomes the young potato plant, and causes it to die down. But the young plant may be sufficiently robust to continue growing, and prevent the fungus gaining the mastery. This may go on until the flowering period is reached, and since it is in the leaves or succulent upper branches that the supplies of food are first exhausted by the fungus, it is there that the fructification first appears. It will be evident that the fungus naturally grows upward, but that is very different from saying that any external sign of its presence must be shown at the base of the stalk.

5. "Perhaps the most serious obstacle against accepting this dormant mycelium theory lies in the fact that, if it is to be used to explain epidemics in the manner suggested, it is almost impossible to get away from the suggestion that practically every potato which is planted is diseased with *Phytophthora* to start with."

This serious obstacle need not stand in the way of the acceptance of this theory, for it must be remembered that starting-points are all that are required, and when once a plant has produced its spores on every leaf, there is abundance to be carried by the wind to infect a large portion of the field. The spores on the under, and sometimes on the upper, surface of the leaf are seen with a magnifying glass as millions of particles of hoar-frost, glistening and perpetually oscillating, so that the slightest breath of wind detaches them, and if they reach a neighbouring leaf or stalk they are sure to stick, from their adhesive nature.

There are still points to be settled in connexion with the life-history of the Irish Blight fungus, but I do not consider that infection, by means of the internal mycelium, is one of them, since the mycelium has been proved to enter the young sprout, and also the young tuber, growing laterally or terminally on an underground branch, or rhizome, or stolon, as it is sometimes called.

#### PERSISTENCE OF VITALITY IN THE MYCELIUM.

The statement is usually made in a general way that the mycelium retains its vitality as long as the potato which harbours it, but it may even persist when the tuber has become quite hard and dried up like a piece of wood. This was strikingly illustrated by means of an infection experiment. A diseased potato, dug on 24th October, 1910, was kept on a shelf where it became perfectly dry, shrivelled up and quite hard. A small portion from the interior, in the form of dust, was inserted beneath the skin of a perfectly healthy Carman No. 1, which was placed under a bell-jar on 24th February, 1911, and not even kept moist. A similar healthy Carman was kept under a bell-jar, exactly under the same conditions, but without being infected.

In the infected potato the disease soon began to show itself, starting from the point of infection. When examined, about the beginning of May, the potato was quite firm, but the disease had extended over fully three-fourths of the surface, and three apparently healthy shoots were produced at the crown end. By the end of May, the three green shoots had been invaded by the fungus and killed, while the entire surface had become brown and turning soft in parts. On making a longitudinal section in the middle of the diseased potato, the interior was brown and hollow in the centre, the only seemingly healthy portion being a little narrow strip beneath the skin at the crown end.

The one half was replaced under the bell-jar, and the other half kept in a moist chamber. The latter in 40 hours produced the fructification of the fungus on the apparently sound and firm portion of the potato at the crown end, while the latter developed sporangia in the corresponding portion in the course of five days. The potato kept as a check remained perfectly sound.

This simple experiment has an important bearing on the vexed question as to how the disease starts afresh each season, when the weather conditions are favorable. The mycelium may be carried over, as we have seen, in the seed potatoes, but it may also persist in the dried up and mummified diseased potatoes.

When such a tuber is placed in a moist chamber, there is no development of the fructification of the fungus, because the tissues are all dead; but when it is broken up, and a small portion placed beneath the skin of a healthy potato, then the mycelium begins to grow. The mycelium is still alive in the dead potato, but it requires the stimulus of the living tissue to change it from the dormant to the active condition. This is well shown in the infected tuber, where the mycelium had invaded and destroyed all the tissue, with the exception of a narrow strip towards the crown end. Where the tissue



still remained alive, there and there only the mycelium was able to develop further, under the influence of moisture, and produce the fructification of the fungus. Such tubers in the field coming in contact with the cut surface of a healthy potato could infect it.

Not only may the mycelium remain dormant in the tubers, it may also persist in the shrivelled-up tops. The old haulms are usually left on the field and ploughed in, so that when potatoes are planted in succession, there is no difficulty in accounting for fresh outbreaks of the disease.

#### SUMMARY OF VIEWS ON INFECTION BY DORMANT MYCELIUM.

It is a recognised fact that the spawn or mycelium of the fungus can live over the winter in the diseased tubers, and remain dormant until the necessary conditions of heat and moisture start it into new life. This life may manifest itself at least in three ways, and each of them may serve to start the blight afresh.

1. A diseased potato lying on the surface of the soil can produce plenty of spores, as shown in Fig. 1, and these spores may be carried to and infect healthy potato plants. Or it can produce spores even in the soil, and these may be carried to the surface by insects, worms, or otherwise.

2. When diseased potatoes are planted, however, the dormant mycelium may not directly produce spores, but grow up into the stalks and foliage, where the spores are produced, as shown in the Frontispiece.

Over half an acre was planted with diseased tubers, so badly infected that they had been sent to the destructor, and I saved them for purposes of experiment. They were grown on virgin soil, isolated from any other potato crop, and, just about the flowering stage, they showed signs of the disease on the foliage.

3. The dormant mycelium may even pass directly into the new tubers from the diseased "sets," without the production of spores above ground. Cases have occurred where diseased "sets" were planted in a garden, and while the luxuriant foliage was perfectly healthy, the new tubers were diseased. The best proof that this takes place is shown in the common occurrence of infection from the stalk end, as in Fig. 2; but potatoes are being grown under straw, and under old rotted sacks, to afford further ocular demonstration of the fact that the mycelium can pass directly into the tubers.

#### PRINCIPAL MODES OF INFECTION.

In discussing how this disease is spread throughout the crop, and how it is introduced into new districts where potatoes are grown for the first time, it is necessary to come to an understanding on one or two points. Those growers who consider that it is entirely a matter of the weather may be left severely alone, but for the large body of producers, who desire to know the real nature of this disease, and are willing to adopt measures for its prevention, there are certain facts worthy of consideration.

First, the disease is caused by a fungus known as *Phytophthora infestans*, for not only is this particular fungus always found associated with the disease, but the disease may be produced in perfectly healthy plants or tubers by inoculation with the fungus.

Second, the disease was introduced into Australia with the potato, and the only known means whereby this could be done was by the spawn, or mycelium, of the fungus inside the tubers. That the sporangia should retain their vitality for a considerable period has in no case been observed, but the mycelium is capable of infection, even after the potato containing it is quite dry and hard. Starting from these two established facts, that the disease is due to a fungus, and that it may be carried in the seed potatoes, let us now see how the disease is spread in a general way.

When a diseased potato is planted and sprouting commences, the mycelium may enter the young shoot and grow inside, keeping pace with the elongating stem, just as in the smut of cereals. It passes from the stem into the leaves, and sooner or later, according to the humidity and heat, reproductive bodies are produced on both stem and leaf. The spores falling to the ground, and reaching the tubers when moist will infect them, and produce the disease as already shown. But this will hardly account for every one of the young tubers being affected, even when not in contact, as in Fig. 110.

A clear distinction must, however, be drawn between the two different modes of infection—by the mycelium arising from the “seed,” or by the spores falling from the leaves—since this has an important bearing on the way in which the fungus reaches the tubers. When infection of the potato plant above ground occurs by means of spores, carried by the wind or other agency, then the mycelium produced may *descend* the stem, until it has reached its furthest end, and then pass along the underground branches into the tubers.

But when the infection of the plant is due to the mycelium inside the seed potato, growing up in the young shoot and extending to the leaves, then even although spores are not formed, owing to the dryness of the atmosphere or excessive heat, the *ascending* mycelium may pass into the underground branches and infect the tubers. Although the view is commonly held that the mycelium ascending the stem from a diseased tuber reaches the leaves, and then passes down the stem to infect the tubers, there is no evident necessity for this round-about method. It is only when the tops are infected by wind-borne spores that the mycelium will pass down the stem and enter the tubers.

#### RESTING SPORES.

The principal known methods by which potatoes become infected have just been given, but there is a suspicion in many minds that there is something in the soil where potatoes have been grown, which may produce infection in otherwise healthy potatoes. This raises the question of resting spores, or oospores being developed underground by the fungus, and remaining dormant in the soil for several seasons. In fungi, closely related to the one which produces the potato disease, bodies are formed which are able to remain dormant in the soil and reproduce the fungus when the growing season again comes round. But in *P. infestans* no such bodies have ever been conclusively proved to exist, and besides, potatoes grown in pots, where diseased potatoes had been produced, did not contract the disease. This particular fungus produces a hibernating mycelium in the tuber, and judging by the widespread distribution of the fungus, it is thereby provided with a much more efficient means of propagation, even under adverse conditions, than would be possible even with resting spores. (Note—p. 100).

#### CONDITIONS UNDER WHICH THE DISEASE OCCURS IN AUSTRALIA.

The discovery of the Irish blight in Australia has brought into prominence the fact that, while the same fungus—*Phytophthora infestans*—is invariably present, it has not always the same apparent effect upon the potato plant, as in countries such as Ireland, where the conditions are so different. So pronounced is the difference that many of the growers, particularly those who have Irish experience of the disease, refuse to believe that it is the same, and stoutly maintain that it is a case of mistaken identity. They assert that there is not the sudden decay and blackening of the tops, with the offensive odour which is so characteristic of the disease in the Old World, and that the

tubers themselves do not at once rot away into an evil-smelling putrid mass. I have carefully inspected the potato fields in an entire district where the disease appeared the previous season, and failed to discover any decisive symptoms of the disease above ground, but on digging up the tubers, the sunken skin, and the rusty-brown markings immediately beneath it, at once revealed the presence of the fungus, which invariably developed the characteristic fructification when kept for a short time under moist conditions. In the great majority of cases it was in the tubers that the disease was definitely proved, although in an exceptionally wet spring like the present (1910), and an equally wet autumn (1911), accompanied by hot muggy weather, the stalks and leaves freely developed the spores, and became black, rotten, and odorous.

The attitude of many of the growers not only in one, but in all the States, is strikingly indicated in the following quotation from a letter received from Mr. George Quinn, of the Agricultural Department, of South Australia:—“There is the usual scepticism exhibited here respecting the identity of the disease. Because the crops do not collapse into a rotten, filthy-smelling mass in a few days, the folks, particularly from Ireland, declare it is not Irish Blight. Most of the growers near Adelaide showed their faith in this fallacy to the extent of planting clean seed on land where the crops went down, and were ploughed under last year. Result—crops planted before September this year on such land gone down completely, and the decided opinions are not quite so loud-voiced against the ‘man with the microscope.’”

While it is generally the case that the tubers affected with the disease, when dug, are quite firm and hard, this only shows that the distribution of the heat and moisture must be taken into account, as well as the nature of the fungus. The dry and hot weather which often prevails while the potatoes are growing, tends to check the development of spores, and to mitigate the severity of the attack. In some districts, for instance, the main crop is planted in June, July, and August, which are our winter months, and sometimes there are heavy rains in July, August, and September, so that there is excessive moisture in the early stages of growth, and sufficient heat to encourage the fungus, which is particularly prolific in sheltered hollows. In such districts the growers have now learned by experience to plant late in order to avoid the disease, that is, about the beginning of September, or early in spring. In other districts the very reverse is the case, for at Fish Creek, in South Gippsland, where the disease was first discovered in Victoria, the crop was planted late towards the end of November, and dug in June and July. In the month of June there were 8·76 inches of rain, and sufficient heat to cause the fungus to develop freely. The early crop may escape the disease, while the late crop succumbs, or *vice versa*, and similar conditions to those prevailing in Australia have been observed at the Cape, by Lounsbury, who writes in his *Annual Report for 1909*:—“The influence of humidity on this disease is very marked. In the eastern districts it is a summer and fall trouble, while in the south-western districts it is a late winter and spring one. Excepting young ones, few potato patches around Cape Town were free from it in October; but in November, when the dry south-east wind began to blow, it disappeared as if by magic.”

No general rule can be laid down in our variable climate, for cloudy, damp, and sufficiently hot weather may occur in the winter months to develop the fungus, or similar conditions may prevail in the spring and autumn.

In Western Australia, the disease was first discovered on 31st August, 1909, and from this onwards through the spring months of September, October, and November, the area affected rapidly extended. It was noted that the



spring of that year was an exceptionally protracted one, the rain continued even until the end of November. When the warmer and drier summer weather set in, the rapid spread of the disease was checked, and from the end of December up to the present, no further outbreaks of the disease has been officially recorded. The great heat around Perth extending to the soil had evidently killed the blight, root and branch, and unless imported in fresh seed, there is no reason why that particular locality should not remain free.

The blight may appear early in the tips of the main shoot, even when the plant is just above the ground, or about three inches high, and the influence of moisture on the development of the disease is very evident where irrigation is employed. In South Australia, the crops are mainly grown during summer, with the help of irrigation, and some which have been attacked gradually dry down. If these are not watered when first beginning to decline, the tubers, though small, do not appear to decay, but if water is applied to stimulate the flagging growth, the tubers either rot straight away or do not keep long. The heat is sometimes so intense that the soil becomes so hot that one cannot bear his hand upon it, and in Adelaide the thermometer has registered as high as 180 degrees Fahr. in the sun.

It has already been recorded that tomatoes are readily infected by spores from the potato, and *vice versâ*, and the practice adopted in some districts of planting tomatoes while the potatoes are growing is not to be recommended. The blight has been found on them in June and July, and the spores might be easily transferred to the early-planted potato crops, just at a time when they are most susceptible.

While the blight has been hitherto most serious with us in districts with a heavy annual rainfall, it is not so much the total amount of rain as the time when it falls that determines the development of the fungus. It may be prevalent in the early crops, which have received the winter rains at the start, and as they are usually grown in sheltered spots, to protect them from frost, they sometimes suffer severely. Or it may be very bad in the late crops, which have received the autumn rains towards the end of their growth, when the fully-formed and mature tubers suffer less than those that are soft and immature.

#### RELATIVE FREQUENCY OF POTATO BLIGHT IN VICTORIA DURING THE DIFFERENT MONTHS.

This disease was first discovered in Victoria in July, 1909, at Fish Creek, but there is little doubt that it existed elsewhere in the State, although unobserved, and that this was not its first appearance. Then, in September, it was discovered at Welshpool, and in November, at Beech Forest, and this was the entire record for 1909.

In 1910, no specimens were received until May, although suspicious-looking potatoes had been examined before that without result. It was then discovered at Foster, not far from Fish Creek, and in every succeeding month specimens were forwarded. In October, the number of specimens received was the greatest on record up to date, chiefly owing to the outbreak in the Warrnambool and Port Fairy districts. During the early months of 1911 the weather conditions were exceptionally favorable, and there was a considerable extension of the disease to different districts. The description of the weather about the middle of March by the Commonwealth Meteorologist was a combination of conditions simply perfect for the spread of blight — "Generally warm and sultry, with scattered rains and thunderstorms." Many of the crops, too, had just finished flowering, and they were at a most susceptible stage.

The following table will show the number of blighted specimens of Victorian-grown potatoes received monthly from the date of the first discovery of the disease, and it affords a rough indication of its relative frequency :—

TABLE II.—NUMBER OF SPECIMENS OF POTATO BLIGHT DETERMINED EACH MONTH.

	1909 Specimens.	1910 Specimens.	1911 Specimens.
January .. .. .	..	..	25
February .. .. .	..	..	22
March .. .. .	..	..	107
April .. .. .	..	..	..
May .. .. .	..	3	..
June .. .. .	..	4	..
July .. .. .	1	7	..
August .. .. .	..	4	..
September .. .. .	2	8	..
October .. .. .	..	26	..
November .. .. .	3	10	..
December .. .. .	..	9	..

Up to the end of March, 1911, the practice of quarantining parishes in which the blight occurred was followed, in order to protect the clean districts, but it was then found that the whole of the potato-growing districts of Victoria were practically infected, and the practice was consequently discontinued, as serving no useful purpose.

#### DISTRIBUTION IN RELATION TO RAINFALL.

It is well known that, while a certain amount of humidity is necessary for the development of the fungus causing the disease, it does not follow that it will only flourish in districts with a heavy annual rainfall. It is more the distribution of the rainfall throughout the year than its actual amount which determines the prevalence of the blight. The disease has now been discovered in all the potato-growing districts of the State. At first the disease was only recognised along the coastal districts, then it extended inland to the plains and tablelands, until now it is found at Bullarto (2,452 feet), the highest potato-growing district in Victoria, as well as at sea-level.

I am indebted to Mr. Hunt, the Commonwealth Meteorologist, for a summary of the weather conditions in Victoria during the first quarter of 1911, when the epidemic had become general all over the State (Appendix I.) The state of the weather recalls that of the great epidemic in Ireland in 1845. During the quarter "the heaviest rainfall was in Southern and Eastern Gippsland, Murrungowar, about 15 miles north-east of Orbost, recording no less than 32½ inches, and Balook, a place 13 or 14 miles north of Alberton, 30¾ inches."

The month of March was also very wet. "In the north the average was exceeded by about 30 per cent., but south of the Dividing Range two to three times the normal amount fell. The greatest excesses were in Central South, and Gippsland, several stations in both areas receiving more than three times the average amount."

As showing how favorable the first quarter of 1911 was for the spread of the blight, as far as moisture was concerned, the rainfall is given at Melbourne, as a centre, at Yackandandah and Tallangatta, in the North-East, 195 and 212 miles inland from Melbourne respectively, and at Beech Forest, in the south, in the direction of Cape Otway, in all of which the blight was found.



TABLE III.—RAINFALL FOR FIRST QUARTER, 1911.

	Melbourne.		Yackandandah.		Tallangatta.		Beech Forest.	
	1911.	Average for 35 Years.	1911.	Average for 20 Years.	1911.	Average for 29 Years.	1911.	Average for 20 Years.
	Points.	Points.	Points.	Points.	Points.	Points.	Points.	Points.
January ..	129	188	191	178	399	174	120	345
February ..	535	169	797	179	456	179	835	250
March ..	750	211	210	309	415	247	898	419
Total ..	1,414	568	1,198	666	1,270	600	1,853	1,014

## TOMATOES AND IRISH BLIGHT.

The tomato is so closely related to the potato-plant, as I have shown in the *Journal* of the Department for April, 1910, that potatoes and tomatoes may be produced on the same plant. A tomato shoot may be grafted on to a potato haulm, and there will be tomatoes above ground and potatoes under ground. Conversely, if a potato stem is grafted on to a tomato shoot there will be only tubers borne in the axils of the leaves.

It was to be expected, therefore, that sooner or later, as in other parts of the world, the disease of Irish Blight would be found attacking the tomato crop in Australia. It has already been found in tomatoes imported into Victoria from New South Wales, as recorded in the *Journal* for January, 1910, also in Queensland, as noted in the *Annual Report*, 1909-10, but I have just found it (April, 1911) for the first time on plants grown in Victoria.

A row of tomatoes, containing about 150 vines, was planted alongside potatoes in the Yannathan district, the seed potatoes and the young tomato-plants being planted at the same time, on 27th December, 1910. About 11th March, the potato-tops began to show signs of disease, and in about a week they all went down with Irish Blight. A few days after the potato-plants had succumbed, the disease was noticed in the tomatoes, when the fruit was forming. When I examined the plot, on 6th April, not a single plant had escaped, and only an occasional ripe and healthy tomato could be found, and it was evident that the tomatoes had been infected from the adjoining potatoes. The tomato-plants were still green and flowering, but the lower leaves were often brownish and withered. A careful examination only revealed the presence of Early Blight on the leaves, so that, although the fungus of Irish Blight may appear on the leaves and stems of the tomato-plant, just as in the case of the potato, it only affected the fruits at this stage. The fruits were the first portions of the plant to be attacked by the wind-borne spores.

Tomatoes were found affected at all stages of growth, from the tiny fruit, not the size of a pea, to the full-grown and large-sized, lobed fruit. There is a brownish discolouration at first in patches, with a tendency to become mottled, and when the fruit is sliced, this is seen to be due to the discolouration of the pulp extending more or less throughout.

Experiments were carried out to show that healthy tomatoes can be infected from diseased potatoes, and healthy potatoes from diseased tomatoes, with the following results :—

1. A healthy green tomato had spores from a diseased potato placed on its skin, in a drop of water. In course of time, the surface around this spot became discoloured and depressed, and in sixteen days the fructification of the fungus was produced.

2. A healthy potato, of the Southern Cross variety, was infected at the crown end with spores from a diseased tomato. In six and three-quarter days the fructification of the fungus appeared in various patches, and the young green shoots of the potato were literally covered at the base with the fungus.
3. A clean tomato was placed in a vessel where a diseased tomato had been freely shedding its spores, and from mere contact with the spores the healthy tomato was infected, so much so, that in nine days the fructification appeared on the surface.

In every case of infection there was a control experiment, in which similar healthy potatoes or tomatoes were kept under exactly the same conditions, but without the fungus, and no blight appeared. So that it has been conclusively proved, while the weather conditions may favour or hinder the development of the disease, it cannot be produced without the fungus.

After the discovery of blighted tomatoes in Victoria plenty of fresh spores were available, and an experiment was carried out to test the mutual infection of spores from potato and tomato under exactly similar conditions, when applied to the unbroken and broken skin. In each case there was only a single point of infection, and each specimen was placed by itself in a closed jar, lined with moist blotting-paper, on 10th April, 1911.

TABLE IV.—MUTUAL INFECTION OF SPORES FROM POTATO AND TOMATO.

No.	Specimen.	Condition.	Infection.	Time Taken to Reproduce Spores.
1	..	Healthy tomato	Unbroken skin	Spores from tomato
2	..	" "	" "	" potato
3	..	" "	Broken skin..	" tomato
4	..	" "	" "	" potato
5	..	Healthy potato (Carman No. 3)	Unbroken skin	" potato
6	..	" "	" "	" tomato
7	..	" "	Broken skin..	" potato
8	..	" "	" "	" tomato

One of the healthy tomatoes and potatoes was kept separately, under moist conditions, without any development of disease.

In nine days two of the tomatoes and two of the potatoes with broken skin, as well as one of the potatoes with unbroken skin, produced the fructification of the Irish Blight fungus. At the end of fourteen days a tomato with unbroken skin also produced the fructification, but no further developments were observed at the end of a month, and the experiment was considered closed.

Thus, a tomato and a potato with unbroken skin, inoculated with spores from a potato, were not infected, owing to some individual peculiarity, but in a previous experiment this infection was successful, and the fructification of the fungus appeared in both instances in sixteen days.

Appended is a short account of the behaviour of each specimen.

No. 1 showed a depressed area of about three-quarters of an inch on the third day, and on the fourteenth day this had increased to fully 1 inch in diameter, but without any noticeable discolouration, and on the margin a

few tufts of the fructification appeared. At the end of the experiment the tomato became soft and rotten, and the diseased patch was overgrown with fusarium.

No. 2 was still firm, and showed no trace of disease.

No. 3 showed a small depressed area at infection point in three days, and on the ninth day, the slightly-discoloured and softened area was about  $1\frac{1}{2}$  inches in circumference, and distinctly marked off from the sound tissue. Tufts of sporangia had burst through the skin over the discoloured area, and even beyond it. At the end, the specimen was completely rotten.

No. 4 was similar to the preceding, and the origin of the spores from the potato did not seem to affect the result. It was completely rotten, and covered with a thick felt of fusarium.

No. 5. The potato remained quite firm, and free from disease.

No. 6. There was no sign of infection on the third day, but on the ninth day there was slight discolouration over a circular area of about half an inch in diameter, and tufts of sporangia were seen bursting through the lenticels, even beyond the discoloured portion. At the end, the entire potato was invaded by the fungus, and tufts of sporangia were produced all over the surface.

No. 7. This specimen showed discolouration on the ninth day over an area of about 2 inches in diameter, and the fructification had burst through, over, and beyond this. At the end, the infection had extended over three-fourths of the area of the potato, and there were two strong apparently healthy shoots and a few smaller ones at the crown end. This was considered a very suitable sample for testing the assertion that the produce of a diseased tuber is not diseased, and it has been planted whole.

No. 8 was similar to the preceding up till the ninth day, and both showed a slight discolouration on the third day after infection. At the end, infection extended all over, and tufts of sporangia were produced very generally over the entire surface.

It has now been conclusively shown that tomatoes and potatoes are mutually infective, and that, even with the tough skin unbroken, spores falling upon them when moist can produce infection, and a fresh crop of spores may appear within nine days.

A diseased tomato, like a diseased potato, may naturally produce spores on the unbroken surface while still attached to the parent plant, the fungus filaments protruding through the skin in both cases. But the tomato differs in producing spores internally as well, for the filaments of the fungus ramifying in the pulp, bear spores freely in the cavities of the fruit containing the seeds.

It is evidently bad policy to plant tomatoes and potatoes side by side, as is often done in our coastal districts, for there is always a risk of one infecting the other, and consequently both crops may suffer. Further, the tomatoes growing in the winter have been known to be affected with blight, and thus the spores may be carried to the young potato crop, and from the potato to the tomato for one-half of the year at least; until the dry heat of summer arrives to hold them in check.

A very simple way in which artificial infection may be brought about is to place sporangia in a small phial of water. After shaking it well up, a drop is placed on the skin of the potato or tomato, and a cut or stab made through the drop into the skin. Twenty healthy potatoes were infected at the same time in this way, and all became diseased, every one showing signs of it in about seven days. When the skin is unbroken there is not the same certainty of infection.

### OTHER PLANTS AFFECTED.

It is always useful to know the plants liable to be affected by a particular disease, because if they are weeds, then they can be destroyed or kept down, and if of economic importance, and cultivated, they require to be protected against it.

It is not at all uncommon on tomatoes, in which it produces a fruit rot, and, so far, in Australia, it has only been found on this fruit in Victoria, New South Wales, and Queensland. It also occurs on various species of *Solanum* besides the potato (*Solanum tuberosum*), and has been met with in Victoria on the Kangaroo Apple (*Solanum aviculare*), as shown in Fig. 119. At Kardella, it was found towards the end of February, 1911, on this plant, which was growing freely among the potatoes, at different stages of growth, some in flower and others in fruit. It occurred on almost every plant, sometimes only on the leaves, where it produces large pale brown patches, with a copious development of spores at the margins, on both upper and under surfaces. It also attacked the stem, and was very common on the young shoots, causing them to turn dark brown, and on the stems it forms dense patches of the mould. Early in March, Mr. Seymour also found it at Fish Creek, where the disease was very bad on the potatoes, as it was also at Kardella.

Although there was plenty of the Black Nightshade (*Solanum nigrum*) growing in the same fields, the fungus was not found on it. I have met with it frequently in potato crops, with the badly-diseased leaves mixed up with it, and yet it escaped, so that it is probably immune. It is liable to be attacked, however, by the Early Blight.

It is interesting to observe the plants attacked by the Potato Moth (*Lita solanella*) for comparison with those known to be infected by Irish Blight in Australia. I am indebted to Mr. C. French, jun., for the list, which is as follows:—Australian Tobacco (*Nicotiana suaveolens*), Black Nightshade (*Solanum nigrum*), Cape Gooseberry (*Physalis peruviana*), Devil's Apple (*Solanum sodomæum*), Potato (*Solanum tuberosum*), Tobacco (*Nicotiana tabacum*), Tomato (*Solanum lycopersicum*), Tree Tobacco (*Nicotiana glauca*), Trumpet Weed (*Datura stramonium*).

It is not recorded on the Kangaroo Apple, which is subject to Irish Blight, but it is found on the Black Nightshade, which appears to be immune to the potato disease.

The average grower regards everything which causes the leaves to turn brown, or the plant to wilt, as a case of "blight," and it is supposed to be of the same nature as potato blight. A great variety of cultivated plants have been sent to me as being affected with the same kind of blight as the potato, and even the common blacken fern, turning brown, has been brought forward as an instance of the prevalence of this disease. But it is a wise provision of nature, as we might say, that these disease-causing fungi are often limited in their scope, and can only infect and gain an entrance into certain plants. While this disease is not confined to the cultivated potato, it is practically not found outside of the potato family, and there is an evident necessity for clean cultivation in general, and the destruction of solanaceous weeds in particular.

### DISEASES ASSOCIATED WITH IRISH BLIGHT.

The occurrence of various diseases along with the blight has already been incidentally mentioned, but it is desirable to point out definitely what diseases are associated together, as some of them are often confounded with it. Thus the Early Blight has been frequently associated with it during the past season, and the curling up and withering of the leaves were often



attributed to that cause. The Irish Blight may attack the potato-plant just as early as the other, but, generally speaking, the Early Blight affected the plants before flowering, while the Irish Blight appeared to be most virulent at or after flowering. *Fusarium* was very frequently associated with it, as well as Wet Rot, and *Rhizoctonia*, and the Black Dot disease appeared along with it under circumstances which suggested that both diseases had been imported in the seed recently brought out from England. It was even found associated with Eel-worm, but only rarely. The appearance of these different diseases together show that they are subject to similar climatic conditions.

The diseases so far found associated with Irish Blight in Australia are Early Blight, Dry Rot, Wet Rot, *Rhizoctonia*, Black Dot, and Eel-worm disease, or "Blister."

#### SUMMARY OF POINTS OF PRACTICAL IMPORTANCE.

The potato blight is a splendid example of a plant disease caused by a definite fungus, and the purely scientific study of its life-history in the laboratory is the basis on which the practical treatment of the disease is founded. Numerous experiments have been carried out with the different stages from spawn to spawn, but only such points will be briefly given as are of practical importance in dealing with the eradication or prevention of the disease.

1. The mycelium of the fungus lives in the tuber, and, under suitable conditions, may develop and propagate the disease.

Hence only clean seed potatoes should be planted, obtained, if possible, from districts where the disease is not known to exist.

2. A diseased potato may communicate the disease to a clean potato by contact, either from the mycelium or from the sporangia growing on the surface.

Hence seed potatoes should be carried in new bags, to prevent any possibility of infection.

3. Potatoes and tomatoes are mutually infective, and the latter, from their succulent nature, propagate the disease very rapidly.

Hence tomatoes should not be grown where diseased potatoes have been, or the reverse.

4. The fungus may pass through all the stages of its life, from sporangium to sporangium again in six and three-quarter days.

Hence the apparently sudden appearance and rapid spread of the disease.

5. The mycelium may produce a crop of sporangia, when young and vigorous, in fifteen hours, and, in the case of tomatoes, in about seven hours.

Hence, to prevent the spread of this fungus from plant to plant, by means of sporangia on the leaves, spraying with Bordeaux mixture or copper-soda solution may be adopted to prevent their formation.

6. Sporangia have their development arrested by the action of formalin.

Hence dipping whole seed-potatoes in formalin will destroy any sporangia on the surface of the tuber.

7. The formation of sporangia is prevented by a dry heat of 80 degrees Fahr., while a moist heat of the same temperature encourages their formation.

Hence the disease is not likely to spread in districts where there is a continuous dry heat of this temperature, about the time when the fungus would produce its fructification.



8. Sporangia lose their vitality if kept dry for twenty hours.

Hence their life is limited, and, even if transported by the wind to a distance, they must reach their proper host-plant, or perish.

9. Zoospores are incapable of germination after being kept dry for twenty-four hours, but they germinate readily in moisture.

Hence mists and dews are sometimes said to cause the disease, because necessary to the production and germination of zoospores.

10. The mycelium inside the tuber is sterilized when subjected to a dry heat of 120 to 130 degrees Fahr. for four hours, without interfering with the growing power of the potato.

Hence seed potatoes could be treated in this way, and secure a district against infection, when planted in ground free from diseased potatoes, and at a suitable distance from other potato-growing districts, where heating is not resorted to.

11. Special seed-potatoes could be imported for trial, even from countries subject to the disease, by submitting the tubers to dry heat, and thus preventing any risk of introducing the disease.

## FACTORS INFLUENCING THE DISEASE.

### HEAT AND MOISTURE.

The controlling influence of the weather has already been dealt with, but the special factors of heat and moisture may be further considered. It would appear that wherever the potato can be grown, there the climatic conditions favorable for the development of the fungus will also be found. These conditions may not be present every season, and it is conceivable that potatoes might naturally be exposed to a dry heat of 120 degrees Fahr., sufficiently long to destroy the efficacy of the dormant mycelium inside. But fresh potatoes are constantly being introduced, and these would probably carry the disease in some of the tubers.

Because the spores of the fungus could not be produced in a dry heat of 80 degrees Fahr., it was firmly believed by many that the disease could not gain a footing in many parts of Australia. Helms, in his Report in 1895, (referred to under Literature) writes as follows:—"Therefore, as the summer heat as a rule exceeds this temperature in most parts of Australia, and undoubtedly in New South Wales, there is little fear that this destructive fungus will establish itself here, if it should be introduced. It is, however, better to guard against its introduction than to depend too much upon the climatic safeguard, because even with the greatest of care, investigators are sometimes led into error."

The past season has shown how the disease may flourish in the States of the Commonwealth, even including tropical Queensland, where the steamy heat rather favours it. The soil temperatures, too, may be sufficiently high to prevent the dormant mycelium developing, and in West Australia 150 degrees Fahr. has been recorded in potato-growing country. While, therefore, a dry heat is inimical to the disease, and might stamp it out altogether, the heat and moisture combined, necessary to the growth of the potato, will always insure its reappearance if the potatoes used for "seed" contain the mycelium, or spawn, of the fungus.

### TEMPERATURE.

There are certain limits of temperature between which this fungus thrives, and it is very important to know these, because certain districts may be more favorable to its development than others, and the virulence of the

disease may depend on the season at which the potatoes are planted, and the time when they are approaching maturity. Thus Eriksson found that no sporangia were produced when the temperature rose to 77 degrees Fahr. on the one hand, nor when it fell to 41 degrees Fahr. on the other. The optimum temperature, or that most favourable for their development, was found to be 72 degrees Fahr., while at 35 degrees Fahr. neither mycelium nor sporangia were produced.

It is important to remember that the temperatures given refer to dry heat. I found that sporangia were not formed at 80 degrees Fahr. dry heat, even when kept at that heat for five days in an incubator, but at 89 degrees Fahr. in a moist heat, they were produced luxuriantly.

The mycelium is also completely sterilized when exposed for four hours to a dry heat of 120 degrees Fahr., and when a small portion of this mycelium was inserted into a healthy potato kept moist, no effect was produced, showing that the vitality of the fungus was completely destroyed.

#### SOIL TEMPERATURES.

W. Catton Grasby, F.L.S., has given a number of readings of soil temperatures for Perth, West Australia, as follows, and they show that there may be sufficient heat in the soil to destroy the mycelium in the tuber :—" Among others are the following—On February 1, with a shade temperature of 107.4 degrees Fahr., a thermometer placed half an inch under the surface of dark sandy loam near the plot in which potatoes had been grown, registered 148 degrees Fahr. On February 13, when the solar reading was 143 degrees, and the shade temperature was 91 degrees, a thermometer supplied to me by the Meteorological Department, registered 150 degrees half an inch below the surface of dark dry loam, and 120 degrees at five inches below the surface. I also quoted the following figures given by Mr. Pfitzer, Science Master of the Perth Modern School :—Shade temperature, 110 degrees ; soil temperature at one inch, 151 degrees ; two inches, 147 degrees ; between four to five inches, 133 degrees."

It must be remembered that the soil when covered with a growing crop would be more shaded than when bare, nevertheless, a temperature of 120 to 133 degrees, four to five inches below the surface, would exercise a destructive effect on any mycelium in the tubers. The ferment, or diastase, which dissolves the starch in the potato, is also then at its maximum activity, and altogether the conditions are favourable for the growth of at least a healthy potato free from blight.

#### SOIL.

The disease has occurred here in every variety of soil and situation, on the hills as well as in the hollows ; but the determining factor is whether the moisture is retained or not. In the gray soils, which dry slowly, keep the moisture well, and allow the water to lodge, the blight is usually worst and appears earliest ; while the red soil in the same paddock, which is loose and allows the water to flow freely through it, may be comparatively free.

But when the spores are formed on the leaves, and are washed down by the rain into the soil, it is found that a greater downpour is required to cause the tubers in the stiff soils to decay than in the loose sandy soils, probably owing to the spores less easily filtering through.

#### CULTIVATION.

There is a good deal of virgin land being brought under cultivation and planted with potatoes, and I have seen instances in the same paddock where a portion of the land previously cultivated was only moderately attacked, while the portion never cultivated was absolutely the worst.

It is generally reckoned good practice not to have the rows too close together, so that there may be plenty of room left for "earthing up," or "moulding." Jensen submitted this to the test of experiment, and found that the tubers covered with a good layer of earth did not suffer much, even although the foliage was badly affected. The spores cannot readily reach the tubers when carried down to the soil by rain or otherwise, hence the lessened infection, but there are drawbacks to the practice in certain soils. In loamy soils the heaped-up earth becomes cracked by the sun's heat, so that the tubers are partly exposed, and if the spores are washed down by the rain they infect them directly. Besides, the sloping sides of the rows readily become dried up by the heat, and this has an injurious effect on the young tubers, and prevents them obtaining their full size. On the other hand, if tubers are not earthed up, they are apt to appear above the ground and be badly attacked by grub.

#### MANURING.

The whole question of manuring in relation to the disease has yet to be studied under our conditions, but there is always the danger of too much being claimed from the treatment of the soil by scientific manuring. It is held by some that all that is necessary to banish the disease is to treat the soil in such a way that the spores present in the soil, and ready to attack the plant when conditions are favourable, should be destroyed. But there is no evidence to show that the disease originates from spores in the soil, and in fact is contradicted by the numerous cases where tubers were blighted in land newly broken up.

Again, it is confidently asserted that the healthy plant, like the healthy animal, defies disease, and that it is only when the general health is lowered that danger arises. It is considered that the resistant quality which confers immunity is the direct result of a properly-nourished system. But while the condition of the plant itself is undoubtedly of great importance, the nature of the parasite has also to be taken into account. With the most scientific manuring the disease is still liable to appear, and while a well-balanced ration in the matter of plant food is desirable, and a proper supply of potash and lime must be maintained to produce a crop, still it is going too far to say that instruction in the elementary principles of scientific manuring is the remedy for this disease.

The diseased tubers possess, according to Lawes and Gilbert, in their dry substance, a higher percentage of nitrogenous matter than the sound tubers, especially the central portion of the diseased tubers. The sap from the brown tissue traversed by the fungus was also much poorer in nitrogenous substances than that from the tissues not invaded by the fungus, so that it would appear that the fungus requires large quantities of nitrogenous substance for its proper growth. In keeping with this, it has been found as the result of numerous experiments in different parts of the world, that the use of highly nitrogenous manures favours the disease, while, on the other hand, potash and phosphatic manures tend to make the tubers more resistant. The use of fresh stable manure is generally considered to favour the disease. In the course of experiments on the manuring of potatoes, Professor Wright made observations on the effect of manurial treatment on the disease. He found that potatoes planted on farmyard manure alone in the drills braird earlier than those planted on artificial manure, either with or without farmyard manure, but at the same time they were liable to suffer from an earlier attack of the disease. On the other hand, potatoes planted on suitable artificial manures alone applied in the drills, brairded more slowly

than those planted on farmyard manure, with or without artificial manure added, but they were not liable to suffer so early from the attack of the disease.

#### TIME OF DIGGING.

The question is often asked, "When should blighted potatoes be dug in order to minimize the loss as much as possible?" and various answers have been given to it.

At the Maine Agricultural Experiment Station (1905) experiments were carried out to test the effect of the time of digging upon the subsequent development of blight, and it was shown that the late dug potatoes were far less liable to blight in the cellar on storing than the early dug about a month before. On the other hand, the evidence at the Vermont Agricultural Experiment Station (1892) pointed the other way. "We are convinced from our observations that the sooner the potatoes are dug after the tops are blighted, the less loss there will be from rot. The common saying that it is better to let the potatoes rot as much as they are going to in the ground, since they will rot to the same extent if dug and placed in the cellar, is wrong and misleading."

The conditions prevailing at the time of ripening have such an influence upon the development of blight, as well as the conditions under which the tubers are stored, that the relation of the date of digging potatoes to the development of blight in storage would require to be settled by experiments conducted here.

After the stalks have died down and growth has ceased, it is generally found that nothing is gained by leaving the potatoes much longer in the ground. As an illustration of this, one portion of the diseased plot at Kardella was dug on 3rd April, and another portion on 16th May, to test the relative amount of diseased tubers on the respective dates.

At the first digging the percentage of diseased tubers was 81, and at the second digging, or six weeks afterwards, it was 49. In the interval the badly-diseased tubers had rotted away, and of course the proportion of healthy tubers had vastly increased. There is always a risk of the disease extending to healthy potatoes, and it is advisable to have the potatoes dug and sorted out as soon as possible.

#### DRAINAGE.

There is no doubt of the value of drainage in checking the spread of the disease, since humid conditions are necessary for the luxuriant development of the fungus. Low-lying and damp spots are perfect breeding grounds, and it often spreads from there as a centre, so that whatever encourages the proper circulation of moisture in the soil and prevents the accumulation of stagnant water, will tend to reduce it.

#### DESTRUCTION OF REFUSE.

Diseased stalks and rotten tubers should be collected and destroyed, either by burning or boiling in the case of tubers. It is known that healthy tubers may contract the disease from being mixed up with the refuse, and probably the mycelium remains dormant in the stalks, just as it does in the potatoes. Blighted haulms should never be placed as a covering to the potatoes bagged in the field, as the spores are liable to infect the healthy potatoes.



## DISEASE-RESISTING VARIETIES.

It is stated, and has been proved in a general way, that the thick-skinned red varieties, rich in starch, are less liable to the disease than the thin-skinned white varieties, poorer in starch or less "mealy." It has also been observed that there is a relation between colour and vitality, or robustness, not only in the tubers, but in the foliage as well. A pale green colour indicates a weaker constitution than a dark green, and such a plant is less resistant than the other.

In countries where the disease has existed for a considerable period, it has been found that some of the varieties are much less liable than others, and it should always be the aim of the grower in raising, testing, or introducing new varieties, to secure, if possible, a disease-proof strain. It is only by local experience and experiment that this can be determined, for under different conditions the same varieties may behave differently.

In Victoria, there was considerable variation among the varieties grown as to liability to blight, but it must be remembered that a single season or two is no criterion. Even in one part of the State a variety such as Snowflake was found to be badly affected, while in another it escaped, so much depending on the time of planting, the age of the seed, the soil, and the season. Among the varieties generally found to be badly affected, the following may be mentioned:—New Zealand Pink-eye, Carman, Snowflake, and Brownell's Beauty, and of these Carman and New Zealand Pink-eye were certainly the most susceptible. There was also a variety known as The Bruce, raised by Mr. Findlay, and introduced in 1886, which was apparently free when dug; but after being kept in the bag for about a month, the disease became virulent in the form of sunken patches and browning of the tissue beneath. The raising and testing of new varieties in a scientific and systematic way should be encouraged, as disease-resisting varieties may thereby be secured, retaining this quality at least for a period of years.

Through the courtesy of F. de Castella, I am enabled to give a list of blight-resistant varieties of potatoes, as recorded by Professor Aumiot in *Progrès Agricole*, for 5th February, 1911. His successive experiments especially those of 1910, which was a very wet year, have fully proved the value of spraying in warding off the attacks of *Phytophthora*. He adds that agriculturists should not hesitate to renew their seed by the adoption of recommendable new varieties.

TABLE V.—NEW VARIETIES RECOMMENDED.

Variety.	Remarks.
<i>Sénateur Edouard Millaud</i> .. .. .	Seedling 1896. Resists well
<i>De Loisy</i> (Dr. Cénas) .. .. .	Very little subject to rot
<i>Goëz</i> (German origin) .. .. .	Very good resistance
<i>Causse</i> .. .. .	Seedling 1884. Resists well
<i>Eiffel</i> (raised by J. Rigault) .. .. .	Good resistance
<i>Président Krüger</i> or <i>Oom Paul</i> (Vilmorin) .. .. .	Good resistance
<i>Géante Bleue</i> syn. <i>Blaue riesen</i> (Paulsen) .. .. .	Good resistance
<i>Wonder of the World</i> .. .. .	Good resistance
<i>Dr. Lucius</i> (Richter) .. .. .	Very resistant
<i>Institut de Beauvais</i> (Brother E. Marie) .. .. .	Good resistance
<i>Professeur Olmichen</i> (Richter) .. .. .	Very good resistance
<i>Fidelios</i> (Rochas) .. .. .	Resists well
<i>Magnum bonum</i> <i>Blaue</i> (Denaiffe) .. .. .	Little subject to rot
<i>Lucien Tisserand</i> .. .. .	Good resistance
<i>Poussé-Debout</i> (Vilmorin) .. .. .	Fairly good resistance
<i>Belle de Juillet</i> syn. <i>Juli</i> .. .. .	Good resistance
<i>Solanum Commersoni</i> violet 1-01 (Labergerie) .. .. .	Good resistance

## SEED POTATOES.

Of all the factors influencing the disease, that of the selection of the seed potatoes is the most important, and ought to be given the first place: but it has already been so much insisted on, that it is only mentioned here in connexion with the age of the seed and the use of sprouted seed.

*Age of Seed—Early and Late Dug.*

This question of the time of digging of potatoes has already been considered in connexion with the development of disease in store, and it is in relation to the development of disease in the crop that the subject is dealt with now, not even taking into account the matter of yield. The age of the seed planted, *i.e.*, the length of time between digging and planting the produce, is supposed to have an effect upon the disease-resisting power, but carefully conducted experiments are necessary to prove the point. It is not a question of mature and immature seed—of seed that has been lifted before it has had time to ripen, and of tubers left in the ground till ripe—but of length of time that they are out of the ground. Thus potatoes were planted by a grower in August, 1909, and dug in March, 1910. They were then thoroughly ripe and hard in the skin, and were pitted in nice clean straw. They were kept in pit for fully three months, and planted in the beginning of July, and when dug in November they were found to be badly diseased. Potatoes said to be of the same variety were also planted in the beginning of November, 1909, and dug in June, 1910. They were pitted similarly to the previous lot, and some of this late dug seed was planted alongside the early dug seed at the same time. The result was that the late dug seed, about three months younger than the early dug seed when planted, was much less blighted (about 5 per cent.) than the latter or early dug seed (about 20 per cent.) There was said to be no difference of soil or season to account for this, and as it is said to have occurred in several paddocks, it was concluded that the age of the seed had something to do with the result. The early dug seed was observed to come up a little quicker than the late dug seed, but the plants were readily affected by sharp winds or frosts, and it was noticeable that while the product of the early dug seed completely succumbed in some instances, that of the late dug seed survived and threw out fresh shoots.

Some of the growers are so convinced of the dangers attendant upon the planting of early dug seed in this particular district where the soil is a rich volcanic, of its greater liability to suffer severely from frost and blight, that they have given up the use of it altogether. They consider that this older seed has a diminished vitality compared with the younger seed. It is played out, as they say, and deficient in vigour, so that it lacks resisting power. I am not aware of any definite experiments carried out with early and late dug seed, but the subject is well worthy of attention.

*Sprouted and Unsprouted Seed Potatoes.*

The system of sprouting seed potatoes has been for a considerable time in use for the purpose of securing early crops, and thereby procuring the highest prices: but it is now found to be so profitable in itself, that the practice is being extended to main-crop varieties. The sprouting of the seed is also known as "greening," or "boxing," or "traying," and consists in placing the tubers, after they are lifted and have become dry, in shallow boxes which are stored in an airy, well-lighted, and well-ventilated shed. The result is that under the influence of light and air, the dormant surface of the tuber becomes active and green, the diastase or ferment renders the starch available for growth, and sprouting occurs.

The advantages of thus boxing the tubers intended for "sets" are :—

1. The production of one or two stout dark-green shoots at the top end of the tuber, instead of a number of weak sprouts.
2. There is no further necessity for handling, as the tubers are placed straight away in boxes.
3. The yield is considerably increased, the average increase being over two tons per acre.
4. The crop matures earlier, and, consequently, can be dug earlier; or it can be planted later, if the state of the weather requires it.
5. Not only is a heavier and an earlier crop produced, but only healthy "sets" need be planted, since any signs of disease are likely to be detected.
6. The tubers can be planted direct from the box.

There are two features of this method which are likely to be of service in dealing with the potato blight. The one is the rapidity of growth, so that the tubers are a shorter time in the ground, and, as a consequence, are likely to be well advanced before the danger from blight arises. The other is, the planting may be delayed for several weeks, if necessary, owing to an unsuitable planting season, without diminishing the yield.

The further advanced the crop is, the less damage the blight is likely to do, and this well-known fact is strikingly illustrated by Professor Wright, in his Report on Experiments on the Seeding of Potatoes :—"It would appear, therefore, that soft immature tubers succumb much more readily to the attack of the disease fungus than fully formed and more mature tubers, and it follows that at the period of the summer, when an outbreak of disease occurs, those crops of potatoes that have advanced furthest towards maturity should suffer less from the attack than those that are in a less advanced stage of growth. The promotion of the rapid growth of the crop during the early part of the summer is, therefore, one of the means indicated for mitigating the destructive effects of the potato disease."

It is because the sprouted seed may become an important means of lessening the loss due to blight that I advocate it so strongly, and those farmers who are so anxious to be supplied with a disease-resisting variety, have here a method ready to their hand, whereby they can increase their profits, and at the same time minimize the risk from disease. The method is so simple that any one can carry it out, and the following description, from Wright's *Standard Cyclopedia of Modern Agriculture* (1910), will give the necessary information :—"To expedite the crop the seed sets should be sprouted before planting. For this purpose, boxes or trays are used. The most convenient pattern is the Jersey box, 24in. long, 12 wide, and 3 deep. The corner pieces are 7in. in height, and strong, so that the boxes can rest on the top of each other when piled for winter storage. There is a cross handle for carrying, which is tenoned into the side pieces, and the whole forms a light, handy, and durable utensil which, with ordinary care, will last for years. The price is about 30s. per 100 completed. Each box holds about 20lbs. The seed potatoes are filled into the boxes until they are level with the sides. No particular care is taken to have eyes set upwards; the potatoes are simply poured indiscriminately into the boxes, and left to bud as nature suggests. If large sets are used, they will be one deep in the boxes, but if a smaller size they may be two or three deep. That does not matter, as the sprouts find their way up through the interstices. When the boxes are filled they are piled up one on the other to any height which may be found convenient. The

boxes should be filled in early autumn, before the tuber has commenced to sprout, so as to preserve the first intention. Immature tubers make the best seed for sprouting, and yield an earlier crop than ripened tubers."

"Light is necessary in a sprouting house to make the sprouts tough and hardy, and no heat need be applied, except to protect from frost."

In sprouting seed it will generally be observed that if any of the tubers are diseased, they sprout much earlier than healthy seed. While examining a field of potatoes badly affected with Irish Blight, at the time of digging early in June (winter), I observed that not only had a number of diseased tubers lying on the ground begun to sprout, but that potatoes still in the ground, and attached to their parent stem, had produced leafy shoots above the ground, in some cases reaching a height of six inches. There was also occasional sprouting in the healthy tubers, even while still attached, but it was quite a common occurrence among those that were diseased. It is known that a potato attacked by the fungus respire more actively than the healthy tuber, and this may have something to do with forcing the growth and causing quicker germination.

It would be at least worthy of trial to set aside a portion of ground for seed purposes, and use sprouted seed. Careful selection of seed is one of the foremost methods of prevention, and has also an important bearing on the success of spraying.

In the *Agricultural Journal of Victoria* for March, 1911, Mr. Seymour, the potato expert, has an article on this subject, in which drawings are given of the trays and sheds used, instructions as to the best time for "boxing" or "traying," and the best varieties to use, and it is pointed out that sprouted seed may be planted eight weeks later than unsprouted.

#### *Storage of Seed Potatoes.*

On account of the prevalence of Irish Blight, increased attention is being given to the storage of seed potatoes, and while "traying" or "boxing" of the seed is recommended, there are simpler means of attaining the same end in our genial climate. The object to be aimed at is to keep the seed dry and secure against frosts, while allowing a free circulation of air and plenty of light. It is not an uncommon practice to lay out the seed under the shelter of pine trees, but this does not protect them altogether against rain, although some growers have provided a rough covering of galvanized iron for the purpose.

In some districts there is plenty of rough timber, and a storing shed may be simply and cheaply erected. Rough rounded timber may form the two sides of the shed, leaving the ends open, with a thatched roof overhead. Wire-netting can be arranged in layers inside, on which the seed potatoes are spread out. A calico tent could also be used for a covering, erected in a sheltered spot, and shelves of wire-netting formed inside for laying out as many potatoes as possible, exposed to light and air. The potato lives and grows, feeds and multiplies, decays and dies, and when it is to be used for "seed," should have plenty of light and air. Even in "pitting" potatoes for domestic use, they should be kept dry and provided with air. This may be simply secured by constructing what the farmer is familiar with as a chaff pit. Upright posts are driven into the ground on each side of the space to be used for a "pit," and palings nailed across so as to allow the air to enter freely. A flooring of dry straw may be provided, and the potatoes piled on this to the required height, with a good covering on top to keep out the rain.

Potatoes are sometimes stored in bags, but this cannot be recommended when they are gathered from a diseased crop.



A bag of badly blighted and rejected potatoes was received on 15th May, 1910. One half was spread out on the floor of the storeroom, exposed to the light, while the other half was kept in the bag alongside. At the end of 15 days (30th May) they were examined. Those on the floor remained dry and firm, drier even than when laid down, and practically without smell, while those in the bag became absolutely rotten and slushy, emitting a vile stench.

There is no doubt that potatoes will keep better and longer when exposed to light and air, than when placed in bags stacked one above the other, as they often are.

### *How the Potato Blight is Spread.*

In order to check the spread of any disease, whether of plant or animal, it is necessary to know how the disease originates, and then to follow its course, so as to step in and either prevent it entirely, or at least to reduce its destructive effects to a minimum. In the case of potato blight, we know that it is caused by a fungus, for we can take healthy plants, as well as healthy tubers, and produce the disease in them by means of this fungus. The weather is a contributing factor, for just as we sometimes sow wheat grains and the absence of moisture prevents their germination, so the fungus will not develop if suitable weather conditions do not accompany it.

From what we already know of the life-history of this fungus, as to its nature, the particular symptoms it produces, and the conditions which favour or hinder it, the various ways in which it is propagated may be more or less fully determined. The starting point is in the tuber itself, for this is the only possible way in which the disease can have reached Australia. As already shown, the mycelium retains its vitality, even in the dried up and mummified diseased tuber, so that the living and the dead may both carry the infection.

The mycelium in the tubers, and the spores are the two principal means whereby the disease is spread, and while recognising both, there is a danger of the one being unduly extolled at the expense of the other. There is no doubt of diseased tubers spreading the blight, but it is equally true that the spores may be swiftly carried from plant to plant, and cause an apparently sudden decay of the tops. A striking illustration of this was shown at Kardella, where hundreds of kangaroo apple plants, which had sprung up in freshly-ploughed land, were badly infected from diseased potatoes growing in the same field.

How the healthy tuber becomes diseased is the main question to be answered, and it is a question of such practical importance, and about which there is so much difference of opinion, that even at the risk of repetition, I will briefly enumerate the possible sources of infection. The answer to this question is also usually so delightfully vague, that it is necessary to be more explicit about it, and an illustration may be given from one of the latest pronouncements—"The disease reaches the tubers either by fungus filaments passing down the stem, or by spores shaken on the soil and washed down to the tubers by rain."

1. The mycelium in the seed potatoes may pass into the new shoots and infect them. The best proof of this is that the diseased potatoes have been planted, and the fungus has developed in the green and succulent stems and leaves, under conditions where infection from outside was impossible. That the mycelium in the tuber grows in, and with, the young plant can be easily and exactly observed.

2. The fructification of the fungus may develop on stem and leaf, as well as on the "apples" or "plums," and the spores may be carried by the wind or other agencies to neighbouring potato-plants and infect them. Spores

have been taken, either direct from the potato, or after being placed in water, and laid upon the leaves of healthy growing potato-plants. The inoculated leaves soon became infected, and ultimately the entire plant above ground succumbed. The spores are easily detached, readily-carried by the wind, and from their sticky nature, adhere to whatever they come in contact with. If this is a potato-plant, and there is sufficient moisture, the spores will germinate; but if not a member of this family, then they simply perish. Before it was so clearly recognised as it is now that the disease is spread through the mycelium inside the tuber, that the sporangia succumb so easily when dry, and that the swimming spores are so short-lived, there was a good deal of exaggeration indulged in about air-borne infection. Worthington G. Smith practically places no limit on the extent of its spread by means of wind-borne spores, for he writes:—"Now if we could imagine the whole of Britain free from the disease, and a single infected field somewhere in France or Germany, a single puff of wind would send the spores over to us, and we should at once be as badly off as if we had suffered from the disease from the first."

Dr. Buller, in his "Researches on Fungi," has pointed out that the spores of all the higher fungi, such as mushrooms, toadstools, and bracket fungi, are very adhesive, just as in the potato blight fungus, and he observed that when examined *in the open* the spores were seen to drift away sideways, and not to be caught up by vertical currents. Now in the case of the potato blight fungus there are some who imagine that the spores are carried upwards, and that they hover over potato fields, ready to be carried down by rain or dropped down in thunderstorms. But there is no warrant for this assumption in the general behaviour of spores, and it is highly probable that in the potato blight the spores may be blown to adjoining fields, but are not caught up in the air and transported for immense distances.

3. The spores may also fall from the leaf to the soil and be washed down by the rain, so as to infect the new potatoes. Some of the potatoes, at least, are reached in this way, and the young tubers can be directly infected, as proved by experiment. The earthing-up, or "moulding," process of Jensen is based on the view that if there is a sufficient layer of earth covering the potatoes, the spores from above will not reach them. The usual course of the disease is that the foliage is first affected, and the leaves are generally almost all killed by the blight before many of the tubers are found to be diseased. At Kardella, where badly blighted potatoes were planted, the fungus was found on every plant about flowering time, sometimes on stems as well as leaf, and not a single tuber was visibly affected. It does not necessarily follow that because the tubers are affected generally after the leaves, it is therefore through the leaves and the stem that the mycelium reaches them. The fungus usually develops first above ground, where the food materials are being manufactured, then it passes along to the tubers where food is being stored, when there is aerial infection.

4. The mycelium may pass down the stem from the leaves, and then along the underground branches, so as to infect the tubers formed upon them.

When potato tops were infected, as already described, the mycelium passed down the stem even to the very tip, and although not a single tuber in this particular case was affected, they were probably moved too soon for the mycelium to reach them.

5. The natural way for the mycelium to pass from the seed potato is along the stem of the young shoot to the leaves. Then as the plant grows, the mycelium in the underground portion of the stem can readily pass along the tuber-bearing branches, as is evident from Fig. 109. In this way the

tubers are directly infected from the ascending mycelium, and explains how the tubers may either be infected from the stem end when the mycelium passes along the underground branches, or at any part of the tuber when infection arises from the falling spores. In the case of infection by wind-borne spores, it is the descending mycelium which reaches the tubers. It is rather difficult to prove the direct passage of the mycelium to the tuber. I have tried growing potatoes by means of "water culture," but the diseased potato invariably rots. However, one is now growing in straw, kept moist, as well as a number planted in my garden, and it may be possible to trace the earliest development of blight in the young tubers.

6. The fungus may spread from tuber to tuber in the soil. It was the wholesale rotting of the tubers, as in Fig. 110, and not only the few sufficiently near the surface to be reached by the falling spores that led to the theory of the descending mycelium infecting them. But the tubers may be infected by the mycelium arising directly from the seed, and also by spores produced by the diseased tubers underground.

At digging time, the fungus is often found growing in tufts from the surface of diseased and decaying tubers, always accompanied by a profuse development of spores. The soil conditions too, when the land is wet and heavy, are evidently favorable for the infection of the tubers, as some of the spores were found to be producing swarm-spores, thus showing that they were in a full state of activity. These spores coming into contact with young, moist tubers could undoubtedly infect them, and thus the disease may be spread from tuber to tuber in the soil. Spores falling from the foliage might start the infection in some of the young tubers, and then it could spread to other tubers in the soil.

7. Even although healthy "sets" are planted, the potatoes left in the soil from the preceding crop may grow and spread the disease by means of spores produced in the ground. This is simply a case of the disease spreading from tuber to tuber in the ground, even when the seed planted is clean.

I have frequently dug diseased potatoes, particularly where the soil was moist, and found the sporangia freely formed on the skin, and capable of infecting adjoining healthy tubers.

8. The rotting haulms and tubers allowed to lie on the ground may also cause infection. The potato shown in the coloured photograph (Fig. 1) was picked up on the field in a damp district, and little tufts bearing spores were scattered all over it.

Professor Marshall Ward has used strong language in referring to the carelessness exhibited by growers, for he writes:—"Of course only a madman would allow the diseased haulms of the potatoes to lie about the ground, or to be placed on the store heaps, or in any way to endanger the crop, if he understood the foregoing facts. It is because agriculturists do not sufficiently appreciate the power of this invisible little enemy that so much apparent recklessness is shown in this respect."

9. "Wild" potatoes have been known to be affected with blight when the main crop has naturally died down and was clean, so that such potatoes should be removed, since the stalks remain longer green and are easily recognised.

10. If healthy tubers are brought into contact with diseased tops while still producing their spores, they may contract the disease. Sound potatoes kept in a bag with diseased haulms became diseased, while similar potatoes kept by themselves under similar conditions remained sound.

11. If the refuse from the potato fields is added to the manure heap and applied to the following crop, there is a danger of infection. The mycelium is not destroyed under these conditions, unless the fermentation of the manure produces a heat of 120 degrees Fahr., so that the only safe plan is to burn the rubbish.

12. If diseased tubers are placed in store, especially if wet or unripe, heat is produced, which causes "sweating," and such a condition is favorable for the production of spores.

These spores will reach adjoining healthy potatoes and multiply, so that the entire mass may become more or less infected. The spores are found on stored potatoes under conditions which show that they have been developed there, and as to infecting the surrounding sound tubers, there is no doubt upon that point, for tubers have been inoculated successfully on cut surfaces, as well as on the unbroken skin, especially when young. It is quite a common occurrence to have boxes of diseased potatoes sent from a distance, and in transit there is a luxuriant development of the fructification on some of the tubers. The tubers should therefore be dry when placed in storage, and kept dry and cool for some time afterwards.

13. Tomato plants are sometimes grown between the potato rows, and they might infect the potatoes, as it has already been shown that they are mutually infective. The fungus has been found on tomato plants in June and July, and the spores might be carried to the early potato crops, just at a stage when they are very susceptible.

14. Native weeds, such as the kangaroo apple, may spread the disease, and such growths should not be allowed to flourish in the vicinity of potato crops.

#### SEEMING CONTRADICTIONS RECONCILED.

I know of no plant disease which is so contradictory in its various phases as potato blight.

I have planted diseased potatoes showing "eyes," but they rotted away and came to nothing. Another similar lot grew and produced only healthy tubers, while the diseased potatoes planted on a large scale at Kardella produced a crop in which every plant was blighted. Percival, in his *Agricultural Botany* (1910), says:—"Several workers at the subject, nevertheless, maintain that from disease-spotted tubers either healthy plants arise or none at all." That is, however, only a part of the truth, as I invariably find that when a number of blighted potatoes are planted, the resulting crop is, more or less, diseased. Massee, on the other hand, overstates the case when he says:—"The produce of a diseased tuber is always diseased."

The most convincing proof can be given that a diseased tuber produces a diseased plant; although it does not necessarily follow that this is always the case. I have dug up the old "set" still attached to the plant which was badly blighted on the tops, and the tubers were also slightly affected, a number of them, however, being marketable. The "set" was found to be diseased and the fructification of the fungus was produced from it in a moist chamber. Further, the mycelium was found in the underground stem ascending from it, and there is no doubt that the plant was infected from the tuber.

Here it is clearly shown that the fungus ascends the stem, reaches the leaves and produces its fructification, but that the mycelium should pass down again to infect the tubers seems to me a most unnecessary procedure, as the mycelium is already in every portion of the stem.

In those cases where the tubers are infected, without any disease being visible in the leaves on account of the prevailing conditions, there is no question of the disease being produced in the tubers from the ascending



mycelium ; and where, as is often the case, infection occurs from wind-borne spores, the tubers are undoubtedly affected from the descending mycelium. But to say that the mycelium ascending to the leaf returns again to infect the tubers, shows a complete misunderstanding of the position, since the ascending mycelium already permeates the underground portion of the stem, ready to pass along the underground branches as soon as tubers are formed. Diseased tubers examined while still attached clearly showed that the infection arose from the stalk and spread from the stalk end.

Then, again, there may be no visible blight appearing on the leaves while the tubers are diseased, and the tops may be diseased while the tubers are still healthy. With reference to the former, I visited all the potato-growing farms in a district previously blighted, and could find no evidence of blight above ground, but on digging some varieties, such as New Zealand Pink Eye, the disease was evident in the tubers. In fact, the spores are not developed on the leaves or stems in bright, dry weather, nor when there is a dry heat of 80 degs. Fahr.

It is a common occurrence in the field up to a certain stage of growth, that the tops may be diseased while the tubers are healthy, and the experiment of infecting the tops proved the same point. It is generally considered that the disease is first visible in the leaves before it appears in the tubers, but this is certainly not always the case under our conditions.

The disease may start from the stalk end of the potato, or it may begin at any part of it. In the former case, the mycelium has passed along the underground branch or rhizome to the tuber (see Fig. 109) ; in the latter, the potato has been infected through falling spores or by means of an adjoining diseased tuber. But there is one appearance I have always found constant, and that is, that the browning of the tissue, due to the fungus, invariably starts from immediately beneath the skin.

There is another contradictory appearance which may be mentioned and which has created a good deal of misunderstanding. The disease may take the form of a dry, brown rot immediately beneath the skin, leaving the potato quite firm and without any perceptible smell, or it may render the potato soft and slushy, giving forth an offensive odour. In the former case, the disease is known as Brown Rust, and it has been stoutly maintained that it is not the blight ; but the convincing evidence of its identity with that disease is the fact that it always gives rise, when kept moist, to the fructification of the potato-blight fungus. In the latter case, the bacteria have come in as scavengers after the dry rot had produced and hastened the decay, causing a putrefactive odour. The blight is sometimes associated with the "Wet Rot" and then the smell is overpowering.

The date of its appearance on the foliage is also subject to great variation, according to the state of the weather. I have seen the mould on the leaves of the potato plant as soon as they were through the ground, but generally it appears at the flowering season or shortly after. The name of the Late Blight is, therefore, not always applicable, for although in Britain it rarely attacks the "tops" before July or August (autumn), with us it is often much earlier, and it sometimes appears along with the Early Blight.

The most contradictory results are often obtained from experiments with one or a few potato-plants.

At Glasnevin Model Farm, the ground beneath diseased potato-tops was covered with a layer of cotton-wool to prevent the spores reaching the tubers, and they remained sound. The conclusion naturally drawn was that the tubers were infected by falling spores, as when precautions were taken to exclude them, there was no infection.

On the other hand, I infected potato-tops, and although spores were produced in abundance, the tubers remained perfectly sound. In this instance, without the use of cotton-wool, I arrived at the same result, showing that experiments with single or a few plants are apt to be misleading unless carefully checked.

Finally, the most variable results are obtained in those cases where the weather exercises a controlling influence. Thus, a grower harvests his potatoes and finds those affected to rot away, while the other potatoes remain to all appearance perfectly sound. He at once jumps to the conclusion, and says—"The theory that Irish Blight spreads to other potatoes is entirely exploded." But when these same potatoes are bagged while still moist, and "sweating" occurs, and they are picked over on arriving at their destination, he is astonished to find that so many of his seemingly sound potatoes have gone bad. The heat and the moisture have encouraged the development of the fungus, and there is no theory, but hard fact, as he knows to his cost, about the disease spreading among the potatoes.

#### DISTRIBUTION OF SPORES BY THE WIND.

The spores of the Irish Blight fungus are produced in immense numbers and in perfectly still air; they may fall vertically downwards on to underlying leaves or the soil. But with air currents they are easily blown about, and may be carried to considerable distances from their place of origin. The wind may travel several miles an hour and carry the spores with it, but since they are slowly, but steadily falling, they must sooner or later descend to the earth.

The distance to which spores may be carried by the wind has attracted a good deal of attention in Australia, not so much for scientific as for commercial reasons, because Western Australia has fixed a limit of 50 miles, and all potatoes sent to that State were required to be grown at least 50 miles from a diseased area. Now there are certain limitations in the very nature of the spore itself, which must be taken into account in practically considering the distance to which spores may be carried. They are not, to begin with, like particles of dust, unaffected by heat or moisture, but they are living things, and, if kept dry for 20 hours, perish. Then, again, they are very adhesive when detached, and whatever they strike against in their aerial rambles, they are likely to stick to. Further, they not only require moisture to germinate, but they must reach some plant of the potato family—another potato, or tomato, or kangaroo apple—in order to survive. In a potato-growing area there is no difficulty in accounting for their distribution and spread, but beyond that they may encounter so many natural barriers, that their chance of survival and reaching a suitable host-plant is very limited indeed.

But, apart from all this, the distance to which spores may be carried may be approximately measured in the open, by means of glass slides smeared with glycerin and alcohol, the alcohol being added to make the glycerin run more freely and be more evenly distributed. These smeared glass slides are fastened to stakes driven into the ground at measured distances from the infected crop, and after exposure for some time (24 or 48 hours), the number of spores caught on the glass plates are counted. When slides facing an infected field in the direction of the prevailing wind, after several trials show no spores, it may be accepted that the limit of their transport has been reached. Arrangements were made for carrying out this test, but the rain interfered and prevented an accurate record being made.

# DEFINITE DETERMINATION OF THE DISEASE.

Amid the conflict of opinion between practical farmers, it is exceedingly fortunate that the disease generally known as Irish Blight can be diagnosed without the shadow of a doubt, either from the leaves or the tubers, since in every sure case of it, the fungus causing it is found associated; and to emphasize this point, I may mention that having had hundreds of specimens submitted to me for my decision, I have never once determined the disease to be Irish Blight without finding the hoar-frost-like mildew on the leaves or tubers, or in the numerous instances where this was not available, by placing diseased portions in a moist chamber, to see if the particular fungus developed.

The fructification of this fungus is so characteristic, that there is no mistaking it, and under the microscope it is just as easy to settle it as to tell an apple, a pear, or an orange tree with the fruit upon it. Not only so, but when this same fungus is found on a tomato or a kangaroo apple (*Solanum aviculare*) the spores are used to infect a healthy potato in order to show whether the disease is communicable from one to the other. In contrast to this certainty based upon facts, we have the farmer offering his opinion on a matter which often does not come within his ken, unless he is accustomed to the use of the microscope, which usually he is not. To him the word blight conveys no definite meaning, but it may be almost anything which causes the foliage of the potato to turn brown and die. This effect may be due to various agencies, insect or fungus, drought or wet, and it is the business of the plant pathologist to assign it to its proper cause, after due investigation.

As an illustration of the different methods adopted by the practical farmer and the plant-doctor in arriving at a conclusion, I may take a supposed case of "water-rot," and the reasons actually advanced by growers themselves. The farmer observes that there is an absence of smell from the affected paddocks and, therefore, jumps to the conclusion that it cannot be Irish Blight. It is a very general impression both with the farmer and the man in the street, that you can invariably tell Irish Blight by the smell, and if that were so, why all this needless fuss about the matter. But it is a well-known fact that the fungus causing this disease produces a dry rot, and it is only when the bacteria of decomposition arrive on the scene as scavengers, provided with the necessary warmth and moisture, that the wet rot sets in, with the disagreeable smell. Potatoes affected with the disease may be firm and dry, and the leaves may become brown and dry up. On the other hand, the potatoes may become an evil-smelling mass, and I have known the plants themselves in the field to give forth an unmistakable odour. Again, it is observed that the majority of the potatoes on the higher-lying land are perfectly sound, but that is no evidence that the disease does not exist on low-lying land. The blight generally starts in low-lying damp spots, and this year in Victoria it was found at the highest point where potatoes are cultivated. Another observation is made by the farmer, which is partly true and partly false. He notices that where the potatoes have rotted in the low and marshy ground, the rot invariably starts at one end and spreads over the whole of the potato, whereas he considers that in the case of Irish Blight, the disease attacks the tuber around the complete circumference and works to the centre. Now, if he had followed Irish Blight in the tuber from its earliest stages, he would have found that it may begin from one end or from any part of the surface according to the point of infection (as shown in Fig. 1), although ultimately it spreads around the circumference beneath the skin. It is a characteristic of this disease that it works from the outside inwards, and to that extent the farmer is justified in concluding that it does not show the symptoms

of Irish Blight ; but there is a want of finality in the whole process of reasoning. Some ultimate court of appeal is evidently required whose decision shall be final, because based upon the essential facts of the case.

The plant pathologist, in his investigations, visits the affected paddocks and sees for himself the conditions under which the potatoes are grown. His experienced eye may be able to tell from the nature of the decaying leaves or the state of the tubers, whether the disease is likely to be Irish Blight or not. But to place the matter beyond the possibility of a doubt, he secures potatoes at different stages of the disease, and by keeping them under suitable conditions for 15 to 24 hours, he can definitely decide if the Potato Blight fungus is present. Of course, if the fungus appeared on the leaves or on the tubers, he would be able to recognise it with a magnifying glass at once.

#### PREVENTIVE MEASURES.

Since it is now well established that this disease is distributed chiefly by means of the seed potatoes which contain the mycelium of the fungus, it is evident that if the tubers free from the disease are planted in a district where the disease does not already exist, there will be no blight. So that we have to distinguish at the outset between districts which are clean and those which are affected, but since practically all the potato-growing districts are affected more or less, the clean areas will be simply those in which potatoes are being grown for the first time.

In the affected areas it would be necessary to get rid of every trace of the disease by the destruction of all diseased haulms and tubers, as well as any potatoes still remaining in the ground. To do this thoroughly, and for the good of the industry as a whole, it would be advisable to put all land which has been under the crop the previous season, out of potato cultivation for, say, two seasons, so that all self-sown potatoes could be rooted out and the land thoroughly cleaned.

The following recommendations, which may seem at first sight rather cumbersome, contain the principal points to be attended to in a condensed form, but for those who object to detail, they are conveniently summed up in a single sentence at the end.

The practical measures for preventing the spread of the fungus may be summarized as follows :—

1. Seed potatoes should be saved from a clean crop, or obtained from a district free from the disease, and carried in new bags.

Potatoes for seed should be carefully selected, drying them thoroughly before storing, and keeping them separate from those intended for consumption.

2. Diseased haulms should be collected and burnt as soon as the crop is dug, since it has been proved that sound potatoes may become infected by contact with such refuse. If the disease has appeared late in the season when the tubers are nearly full grown, it would be advantageous to remove the haulms at once.

When the haulms have been destroyed by blight and they are no longer green, no further growth in the size of tubers will take place, and the crop should be dug without delay.

3. "Wild" potato-plants should be promptly removed from the crop since the stalks remain longer green, as they have been known to be affected with blight when the main crop had naturally died down and was clean.

4. Diseased tubers should either be destroyed by burning or boiled before being used for pig-feeding. They boil hard with the skin unbroken.



5. Do not plant early and late varieties alongside of each other.

6. Tomatoes should not be planted with potatoes, since healthy tomatoes can be infected from diseased potatoes, and diseased tomatoes can infect healthy potatoes.

7. Avoid planting potatoes in immediate succession to crops affected with disease. In fact, a rotation should be adopted so that potatoes will not occupy the same ground oftener than once in three or four years.

8. Use sprouted seed for planting, since the tubers mature more quickly and are, therefore, a shorter time in the ground, and the time for planting can be better regulated.

9. Clean cultivation and keeping down of weeds is a safeguard, since there are some, such as the kangaroo apple, which produce spores in abundance and disseminate the disease.

10. It is a wise precaution to steep the seed potatoes for three hours in a solution of formalin, prepared at the rate of a 1-lb. bottle to 40 gallons of water. This will destroy the effect of any spores adhering to the surface of the potato, although it will not influence the mycelium or spawn inside.

11. When the rows of potatoes are "earthed" up, or "moulded," so that there is a greater thickness of soil covering the young tubers, there is less chance of the spores of the fungus reaching them.

12. Spray with copper-soda solution or Bordeaux mixture. The object of spraying is to prevent the development of the disease, and thus prolong growth until the tubers are fully grown. Incidentally, there is a longer period of growth and an increased yield.

Spraying of the potato-plants is such an important operation in the prevention of blight that it is specially dealt with in a succeeding chapter.

**Clean seed and clean cultivation, rotation of crops and spraying, and avoiding too close planting, are the best known means for combating Potato Blight.**

#### "STEEPS" FOR SEED POTATOES.

There is a very general impression among potato-growers that if you steep seed potatoes in a solution of copper sulphate or bluestone, just as seed wheat is pickled for the prevention of stinking smut, you will overcome the blight. This solution will destroy any spores on the surface of the tuber, but it does not penetrate beneath the skin and, therefore, does not reach the mycelium or spawn of the fungus inside. I carried out experiments with formalin to test its effect on both the mycelium and sporangia.

A diseased potato was cut in slices and placed in formalin (Cuming, Smith's solution) prepared at the rate of 1-lb. in 40 gallons of water, for three hours. On the second day there was a luxuriant growth of *P. infestans*, thus showing that formalin of that strength does not destroy the mycelium inside the tuber.

Sporangia were placed on a microscopic slide in a solution of formalin of similar strength to the above. They were watched continuously for five days, but no germination occurred, while sporangia from the same potato, but placed in water, produced zoospores in great abundance. Sporangia placed on the microscopic slides produced their zoospores in water in less than an hour, and in every slide the zoospores were observed swimming about. These zoospores came to rest, and ultimately germinated freely.

While formalin does not destroy the internal mycelium of the fungus, it prevents the sporangia developing further, and since they may happen to be on the surface of the tuber, I recommend dipping in formalin as an extra precaution against the Potato Blight.

Potatoes were steeped in a solution of bluestone at the rate of 1-lb. in five gallons for one quarter of an hour, and this treatment did not interfere with their growth.

#### PREVENTION OF POTATO BLIGHT BY SPRAYING.

In the leaflet issued by the Department of Agriculture and Technical Instruction for Ireland on the Prevention of Potato Blight, the value of spraying is shown in the results of experiments, and the following statement regarding its utility is made:—"The experience of recent years has conclusively proved that the loss caused by Potato Blight can be, to a great extent, prevented by spraying—an operation which has now come to be regarded as an essential part of the work connected with the successful cultivation of the potato crop. The reports received by the Department from a large number of districts show that those who take the trouble to carry out the work properly are abundantly rewarded, while those who neglect to spray suffer heavy loss, both in the quantity and quality of the crop."

As the result of eighteen tests conducted by the above Department, there was an average increase of  $2\frac{1}{2}$  tons per acre from sprayed over unsprayed plants with copper-soda mixture, and in fifteen tests with Bordeaux mixture the average increase was nearly  $1\frac{3}{4}$  tons per acre. The increase is due not altogether to the suppression of fungus, but partly to the beneficial effect of the spray on the nutrition of the plant.

It is not, therefore, surprising to find that the practice is becoming more and more common as its advantages are realized, and the latest official report states:—"Some idea of the recent progress made in this matter of spraying may be gained from the fact that during the last three years nearly 4,000 spraying machines have been sold through the efforts of the Department in the congested districts of the west of Ireland alone."

The efficacy of spraying is no longer called in question by any one who has given it a fair trial, but for those who have suffered severe loss in their potato crops during the past season, the following facts, gleaned from local experience, should convince them that it pays to spray. In the minds of many, the weather is the controlling factor, but during this season, which has been the worst on record for the encouragement of fungus diseases, the results obtained both with Black Spot of the apple and pear, and Irish Blight of the potato show conclusively that spraying done thoroughly at the proper time and with the proper mixture, saves the crop in spite of the weather. Since the leaves of the potato-plant are rough and hairy, the spray requires to be forcibly applied in order to reach every portion of the surface.

About the middle of February a local grower sprayed 4 acres of potatoes with the copper-soda solution by means of a motor pump, when the tops were luxuriant, using 70 gallons to the acre, and reckoning the cost of labour and all materials at 7s. 6d. per acre. They were again sprayed in about a fortnight, and the result is given in the following communication.—

"Although I have blight on my farm, the sprayed potatoes are remarkably free from it. I have just dug a hundred bags, and there was not one per cent. infected, and a strip not five chains away—a few rows that I did not spray—are completely rotten. The disease in this district is in a most

virulent form, the hot, misty, muggy weather made a heart-breaking mess of things, the disease appearing simultaneously over a very large area, hardly missing a farm, and leaving ruin everywhere."

Kirchner, in Germany, has carried out spraying experiments with very variable results. In 1897, potato plants were sprayed four times with a 2 per cent. Bordeaux mixture, and if the yield of the unsprayed plots is represented by 100, the average of the sprayed plots was only 69.4 per cent. of tubers, and 68.4 per cent. of starch. It is assumed that the Bordeaux mixture acted unfavourably on the production of starch; but here again the weather factor has to be taken into account, for the summer of 1907 was very cold and cloudy, and the investigator doubted whether the same results would be obtained during a bright, warm season. In all these cases the nature of the seed planted has not been taken into account. It is too often assumed by the farmer that he does not need to be too particular about the selection of his seed, especially when he sprays to prevent the disease. But it has been already shown, and it is here emphasized that if diseased "sets" are used, the spraying will not be so successful, apart altogether from the quality and the extent of the yield.

The good effects of spraying, even when done rather late in the season, were shown in the experimental plots at Kardella, planted with badly-blighted seed potatoes. It was originally intended to spray a few rows with the copper-soda solution; but it rained so heavily on the date of our visit for this purpose, that it had to be abandoned. However, on 6th March, two rows were sprayed, when the tops were badly blighted, but still partially green, mainly to see the effect of the spray on the foliage. It rained heavily just before the spray was applied. About a month afterwards (3rd and 4th April) the potatoes were ready for digging, and the sprayed rows were conspicuous from the greenness of the foliage, while the others were brown and withered. The spray was still visible on the leaves of many of the plants, although a considerable amount of rain had fallen since the time of application.

Two sprayed and two unsprayed rows were selected alongside each other, in order to test the proportion of diseased tubers in each, and after digging and weighing, the results were as follows:—Sprayed 55 per cent. diseased, unsprayed 81 per cent., thus showing 26 per cent. healthy tubers in favour of the sprayed portion.

Eight unsprayed rows were next dug and weighed, and 81 per cent. were found to be diseased.

The proportion of diseased tubers in a number of rows was so consistent that the above figures may be taken to represent the gain due to spraying even so late in the season, viz., 26 per cent.

There was a considerable amount of "wet rot" present, but this was so frequently associated with the blight that no distinction was made.

It is the intention of the Department to conduct spraying experiments in different districts, so as to show the effects produced when properly done. A number of growers have sprayed this season without obtaining any definite result, but this could usually be traced to some important omission. There was either a want of thoroughness in not spraying the under as well as the upper portion of the foliage, or the force applied was insufficient. Besides, it was a very rainy season, and the mixture was sometimes applied but afterwards washed off. The copper-soda solution has great adhesive power, and at Kardella it was found still adhering to the foliage a month after the application, even although there had been frequent rains, but spraying should not

be done when it is raining. The new-born zeal for spraying was not always according to knowledge, and as Newton has said, "zeal without knowledge is like expedition to a man in the dark." Some growers confessed to having sprayed ten to twelve times, under the mistaken notion that if plenty of the solution was used frequently, it was immaterial as to the method of application. The type of spraying machine used is very important, and this, together with the best time and method of application of the spray, will be clearly demonstrated next potato season.

The question is often asked, "Should the spray be applied to both the upper and under surfaces of the foliage?" and the answer depends on the view taken of the action of the spray. If it acts simply as a protective coating, then the more thoroughly the surfaces are covered the better. But if, as some think, the spraying material is partially absorbed, then spraying on one side, and particularly the upper side, would serve the purpose. It will be necessary to conduct experiments to settle the point, spraying the upper, the under, and both surfaces by means of a knapsack sprayer and noting the results.

#### *Sulphate of Copper and Washing Soda Recommended as a Spray.*

The spraying mixtures recommended are either of the two following:—

1. Sulphate of copper or bluestone, and washing soda.
2. Sulphate of copper and lime.

The former is recommended by preference for the following reasons:—

1. It adheres longer to the foliage of the plants, and is not so readily washed off by rain.
2. It is more easily prepared.
3. It is not so liable to clog the nozzles of the machine, because if the mixture is carefully prepared there should be no sediment.

#### *Preparation of the Mixture.*

The mixture is made in the following proportions:—

8 lbs. sulphate of copper.  
10 lbs. washing soda.  
40 gallons water.

The sulphate of copper is dissolved in a barrel or wooden tub, because the solution has a corrosive action on metal. Pour into the barrel 35 gallons of clean water. If there is any grit or foreign material in the water it should be strained through a piece of hessian, so that it does not clog the nozzles of the sprayer.

The 8 lbs. of sulphate of copper should be tied up in a piece of hessian and moved about in the water in the barrel until the crystals are all dissolved. The operation is hastened if the crystals are previously ground.

Next dissolve the 10 lbs. of washing soda in five gallons of water in a separate vessel. Then pour the washing soda solution slowly into the copper sulphate solution in the barrel, stirring continuously, and the mixture is ready for use. If convenient to have hot water, both the sulphate of copper and the washing soda can be more quickly dissolved, and the required quantity of cold water can afterwards be added. A quarter of a pound of Paris green may be added to the 40 gallons if it is desired to destroy grubs as well. There is no harm in dissolving the sulphate of copper and washing soda in separate vessels



and keeping them in that condition for several days, but once they are mixed together, the mixture should be applied *immediately*. The mixture deteriorates rapidly even when held over for one day, and is then much more readily



"AUTO" SAFETY KNAPSACK SPRAYER.



COPPER KNAPSACK SPRAYER.

washed off the plants by rain. The freshly-made mixture should always be used. Sulphate of copper is poisonous, therefore the vessels in which the mixture has been prepared should not be used for holding food or water for consumption.

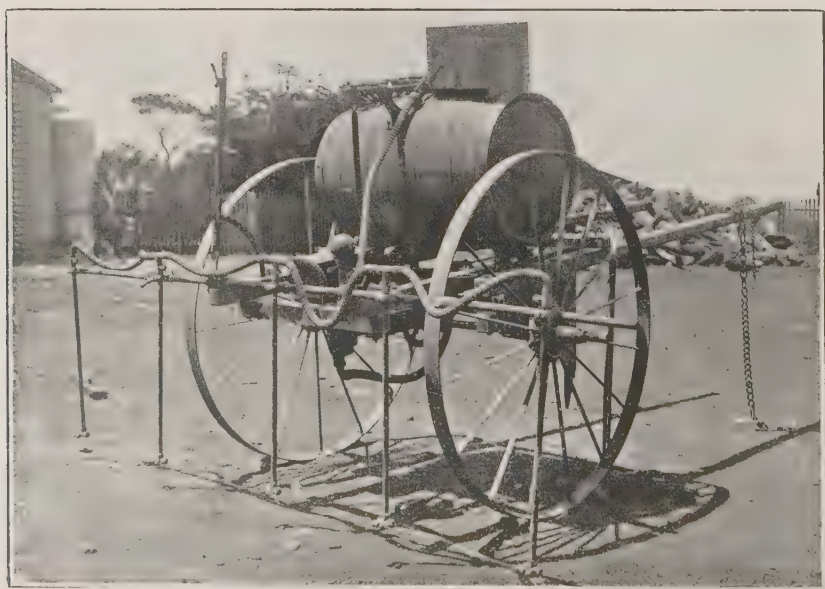
*Application of the Mixture.*

Spraying should be done before any signs of the disease have appeared. It is desirable to apply the first dressing when the plants are about six inches high, although leaves are sometimes blighted as soon as they appear above ground. A second spraying should be given when the foliage is well developed, and if the season is a wet one, a third dressing may be advisable. It is the experience of potato-growers generally that there are two periods in the life of the potato-plant, when it is most easily infected by the Irish Blight fungus. The first is while it is still young and tender and growing rapidly, and the second is when the tissues are fully formed and the flowering stage has been reached. It is a well-known fact that the tissues are much more susceptible when growing than when fully formed; but to counterbalance that, although the tissues have reached maturity in the second stage, the plant is particularly rich in food substances on their way to the tubers. If dull, wet, muggy weather sets in at this period, the fungus revels in the rich supply of food and spreads throughout the plant with amazing rapidity, which is reduced to a black, decaying, foul-smelling condition within twenty-four hours. The foliage should be completely covered by the spray in the form of a fine mist, and this is best done when a sufficiently high pressure is maintained in the sprayer. Spraying should be done during dry weather and suspended when it is raining. If heavy rain has washed the mixture largely off soon after spraying, then it should be repeated.

It is essential to success that the spraying material is kept intimately mixed by constant agitation during the operation.

*Quantity per Acre and Cost of Materials.*

It is found in Ireland that an average crop with fully-developed foliage requires about 100 gallons per acre, and with a small amount of foliage the quantity would be less. The quantity will vary, but the main point to be attended to is to use sufficient to completely cover the foliage without drenching the ground.



FLEMING'S HORSE-POWER SPRAYER.

At the present market price of the articles when bought in quantity, the cost of the raw materials of spraying an acre would be as follows :—

Sulphate of Copper, 20 lbs. at 2 l. 0 <sup>3</sup> / <sub>4</sub> l. per lb.	=	4s. 7d.
Washing Soda, 25 lbs. at 0 <sup>3</sup> / <sub>4</sub> d. per lb.	..	= 1s. 5d.
Total	.. ..	6s. 0 l.



SPRAYING WITH THE FLEMING MACHINE.

### Woburn Bordeaux Paste.

In the *Journal of the Department of Agriculture and Technical Instruction for Ireland*, April 1911, results of spraying experiments are given, and since, during 1910, the Potato Blight was very virulent, it was regarded as “almost ideal for the testing of spraying materials.” All the plots were sprayed at the rate of 120 gallons per statute acre at each spraying, and the materials used were lime Bordeaux, limewater Bordeaux, in the form of Woburn paste and copper-soda solution. The Woburn paste was used as recommended, at the rate of 15 lbs. per 100 gallons of water. There were four centres, and at three of them two sprayings were given, and only one spraying at the fourth. In every case the haulms died down sooner in the plots sprayed with Woburn paste than those sprayed with copper-soda solution, and, on the average of the four centres, “the plots sprayed with the copper-soda gave 23 cwt. of saleable potatoes more, and 3 cwt. of diseased potatoes per statute acre less, than the plots sprayed with Woburn paste.” Farmers were therefore recommended to prepare their own mixtures, owing to the increased yields, and the greater protection against the blight thereby secured.

### Field Trial of Spraying Machines.

In order to show the sprayers at work, several of the best machines were tested at Bungaree. They were of various patterns and prices to suit the small as well as the large growers. There is a knapsack sprayer adapted for areas of only a few acres; and a powerful machine, such as the motor spray pump, which can be used for spraying the most extensive plantations as quickly as possible.



The larger machines were charged with 40 gallons of the copper-soda mixture and the application of the spray, together with its regular distribution over the crop, was closely followed by over 200 farmers. Each machine sprayed five rows at a time and 100 gallons would cover from 1 to  $1\frac{1}{4}$  acres. Of course, more extended trials would be necessary to test the capabilities of each machine for spraying cheaply, quickly, and effectively, and no attempt was made to place them in order of merit, although the performances of each were keenly discussed.

The following machines were exhibited in action, and the accompanying photographs will give a good idea of their general structure and mode of working.

1. *Knapsack Sprayers*.—A copper Knapsack sprayer is shown, capable of holding 5 gallons and is to be preferred to one made of galvanized iron, because the iron extracts the copper from the mixture and thereby renders it less efficacious. The cost is from £3 upwards.

The other represented is known as the "Auto" safety sprayer, and is made of galvanized steel, with asphaltum paint inside. The cost is £3 for 2-gallon size and £6 for 5-gallon size.

2. *Fleming's Horse-power Sprayer*.—This is a comparatively light machine, as the weight is about 10 cwt. when the barrel is full. The wheels can be moved in or out to suit the width between the rows. The spray never comes in contact with iron, as it passes through brass, armoured hose and a copper tube. The armoured hose is warranted not to collapse. By means of a couple of levers easily controlled, the sprays are lifted at the end of the rows and the mixture is, at the same time, cut off at the tank. As soon as the



L. B. & D. MOTOR SPRAYER.

machine is in position for spraying the next set of rows, the levers are reversed and a fresh start is made. Duplicates of the different parts are kept in stock, so that they are easily replaced when necessary. The complete cost is £30.

3. *L. B. and D. Motor Sprayer*.—This consists of an engine, pump and vat. The engine runs at 500 revolutions per minute, and has a pressure



from 150 to 300 lbs. It is fitted with a governor, which enables it to run at any desired speed, and has a magneto instead of a battery. The engine can be completely disconnected in five minutes, and may be used for other work, such as chaff-cutting, pumping water, &c. Cost of the engine, £36.

It is attached to two 2½-in. plungers, and the pump has a triple agitator. The droppers of the sprayer are on the stump-jump principle and have also guards to protect the sprayer. The vat is U-shaped to allow of thorough mixing of the ingredients. It holds 80 gallons, and when fully charged the entire weight is about one ton.

Cost of engine, pump and sprayer, £67 10s. ; and if mounted on a cart as in photograph, £77 10s.

4. *The Forbes Sprayer*.—This machine is made at Bungaree, and when barrel is full, containing 100 gallons, weighs 17 cwt. It is built on steel



FORBES' HORSE-POWER SPRAYER.

wheels with steel axle adjustable. also fitted with ratchet gear for turning, and driven with chain from centre of axle off sprocket wheel. The pump is



FILLING BARREL OF SPRAYER BY FORCE PUMP.

driven with eccentric and can be used to fill the barrel instead of bucketing, thus saving time and extra help. The pump is brass lined, double action and fitted with air-chamber, a continual stream of water being forced back into the barrel; the solution is thus kept well agitated. The machine is



THE FORBES SPRAYER AT WORK.

adapted to do 5 or 7 drills at a time, and the nozzles are adjustable. The spray is circular and can be regulated to any angle. The droppers of the sprayer are fitted with swivel joints and are not injured by striking any obstacle.

Every machine is thoroughly tested before being sent from the factory and the complete cost is £30.

The machines are manufactured or sold by Messrs. Langwill Bros. and Davies, Melbourne; Messrs. Edwards and McGinness, Melbourne; and Mr. W. H. Chisholm, Bungaree.

#### DISINFECTION OF THE SEED POTATOES BY MEANS OF DRY HEAT.

While it is generally recognised that the Potato Blight is largely dependent on the weather for its development and spread, yet there is something which has to pull the trigger before the gun will go off, something which affects the plant in the particular way characteristic of this disease, and that is the fungus *Phytophthora infestans*. Whenever the fungus origin of the disease is clearly understood, and that the weather alone cannot produce the symptoms, then we have something definite to deal with in seeking a remedy or some means of prevention.

After a thorough study of the life-history of the fungus, and the conditions under which each of its stages passes its existence, pathologists have come to the conclusion that the two main lines of attack are (always presuming that clean "seed" in clean ground at a proper distance from affected areas is the first line of defence) either to prevent the formation of spores in the aerial portions of the plant by spraying, or to destroy the spawn, or mycelium, in the seed potatoes by dry heat.

These are the two alternatives at present, and while spraying at the right time is an undoubted means of saving the crop to a large extent, yet it does not get rid of the disease. Heat, on the other hand, is used to stamp out the disease, because it destroys the cause of it in the seed potato itself.

Of course, if a guarantee could be given that only clean "seed" was planted in infected districts in fresh ground at a sufficient distance from a blighted area, and that no potatoes were grown, say for a couple of seasons at least, in the fields in which Potato Blight had been found, there would be no necessity for using heated seed. But there is always the risk that reputed clean "seed" may be slightly affected, so that not even an expert could detect it on a cursory examination, and dry heat is therefore being tried for stamping out the disease under the conditions which prevail in Victoria.

There are various liquid disinfectants used as "steeps," but these can only affect the outside of the potato. The corky skin of the potato is impervious to moisture, and even where the skin is broken by the eel-worm, there is a corky skin formed beneath the wound (as shown in Fig. 56).

Both sound and "scabby" potatoes were steeped in formalin and corrosive sublimate respectively, and even after being in the liquid for four hours there was no penetration beneath the skin. Steeped in a solution of iodine for some time, which gives a blue coloration to starch, there was no change of colour produced when the skin was broken.

But it has been proved that the mycelium inside the tuber is sterilized when subjected to a dry heat of not less than 120 degrees Fahr. for four hours, without interfering with the growth of the potato. Not only have diseased potatoes been repeatedly subjected to a certain temperature for the necessary time with the consequent loss of power of the mycelium to produce a fructification, but the virility and vitality of the fungus have also been destroyed, as shown by its inability to produce infection in a sound potato, as it usually does when inserted beneath the skin and kept moist.

#### THE APPLICATION OF DRY HEAT.

The discovery that dry heat prevented the development of blight was made quite accidentally about 1855, although it was only published as a remedy for the potato disease in 1861. A certain Professor Bollman received some seed potatoes for trial, and they happened to be stowed away on the back of the stove used for heating his study, and forgotten. They were afterwards found shrivelled up, and as a matter of curiosity were planted in 1855 to see if they would grow. They produced a crop with all the good qualities claimed for them, and next season were heated and again planted. It was observed that while surrounding potato-plants were affected with blight, those from heated seed were free from it. In 1857, a larger plot was planted, with the same result, and the professor had then a drying-floor erected on his estate for the heating of potatoes on a large scale before planting.

The exact temperature to which the potatoes were subjected was not stated, and there is no conclusive proof that the dry heat destroyed the disease, yet the erection of drying-kilns showed that the heat was believed to produce that effect.

The next record of the application of heat is by J. L. Jensen, of Copenhagen, as given in the *Gardeners' Chronicle* for 1884. It is shown there that it is possible to kill the fungus in tubers, without injury to the germinating power of the potato, by means of dry heat.

The experiments were carried out in 1883, as well as subsequently, and the conclusion given in Jensen's own words is "that to kill the mycelium the tubers themselves must have acquired and maintained the temperature of at least 40 degrees C. (104 degrees Fahr.) during four hours." He also found that sporangia were not formed at a temperature of 77 degrees Fahr. It may be asked why, if the process of disinfection of seed potatoes by means of a dry heat raised to 104 degrees Fahr. inside the tuber has been definitely



known for over half a century, it has not been adopted in practice. This is probably owing to the difficulty of treating potatoes on a large scale, for while Jensen gives a drawing of a convenient apparatus for treatment on a small scale, consisting practically of a water-bath, he adds—"On a large scale this may be done in a properly constructed oven where the temperature is carefully watched during the whole time."

As the result of numerous experiments during 1909-10, it has been found that a dry heat, not less than 120 degrees Fahr., and not more than 130 degrees Fahr., destroys the vitality of the spawn in the tuber without injuring the growing power of the potato.

This has been tested practically, not only on a small scale in a water oven, but on a large scale in a fruit-drying plant. Healthy potatoes so treated have been grown at Burnley Horticultural Gardens, and diseased potatoes in a quarantined area.

In the heating tests it was observed that seed potatoes dug late stood the heat much better than those dug early in the season.

#### EXPERIMENTS WITH HEATED AND UNHEATED SEED POTATOES AT BURNLEY.

Although I have demonstrated conclusively on a small scale that potatoes affected with the Irish Blight can be heated, and the spawn of the fungus destroyed without interfering with the growing power of the potato, it is necessary to show that the process can be carried out on a commercial scale, if it is to be generally adopted by the grower. The grower has to be convinced, first of all, that heating the potato to a certain temperature will not "cook" it, as he expresses it. Accordingly, at the Burnley Horticultural Gardens, with the co-operation of the Principal, I was able to grow heated and unheated potatoes side by side.

Five varieties of potatoes, viz., Coronation, Up-to-date, Clarke's seedling, Fox's seedling, and Carman No. 1, were heated on 25th July, 1910, in the disinfecting apparatus. They were heated for four hours, and the temperatures recorded were as follows:—

Start .. ..	120 degrees Fahr.
End of 1st hour .. ..	126 degrees Fahr.
End of 2nd hour .. ..	126 degrees Fahr.
End of 3rd hour .. ..	126 degrees Fahr.
End of 4th hour .. ..	126 degrees Fahr.

The internal heat of the potato reached 117 degrees Fahr.

The heated potatoes were planted alongside unheated potatoes of the same variety on 28th July. The result was that the heated potatoes germinated equally well with the unheated. They were all dug on 30th December, and the potatoes from heated and unheated plots were equally good.

Having shown that potatoes can be heated to a certain temperature and grow freely, the next step was to carry out experiments on a small scale with blighted potatoes that had been heated.

In a bird-proof enclosure at Burnley Gardens, used for wheat experiments, blighted potatoes that had been heated and derived from different sources were planted. Irish Blight had not appeared in the Gardens, so that there was no danger of infection from wind-borne spores. They were all planted on 19th September, 1910, in ground where wheat had been grown the preceding year, with the following results:—

1. Two potatoes were planted, but only one came up and grew luxuriantly, quite normal and healthy. On 24th January, 1911, the potatoes were dug, and the yield was 20 marketable and 26 small. They were perfectly healthy, and no sign of blight appeared in the tops or tubers.



2. Five potatoes were planted similarly, and four of them grew up quite healthy and produced potatoes which were quite sound. The odd one did not grow.

3. Seven potatoes of the Factor variety were also planted, and every one of them grew up healthy, producing sound tubers.

4. Two potatoes planted only produced one healthy plant, the other "set" having rotted. Six sound potatoes were produced by the one healthy plant.

Here were four distinct tests of planting blighted potatoes that had been heated, and no blight appeared in the plants or their produce. In every case similar potatoes to those planted, but unheated, were kept in a moist chamber and developed the fructification of the fungus.

It may be contended that the spawn of the fungus, even although alive, did not reach the growing part of the seed potato, but why in every one of the four cases tested.

It is also held by some that blighted potatoes when planted either produce healthy plants or none at all, but experiments now to be considered will show the fallacy of that statement.

#### EXPERIMENTS WITH HEATED AND UNHEATED BLIGHTED SEED POTATOES AT KARDELLA.

It only remained now to arrange for heating blighted potatoes on a large scale, and for planting both heated and unheated diseased seed in a quarantined area. A fruit-drying factory at Harcourt seemed the most convenient for the purpose of heating.

There was some delay in securing the necessary land at Kardella, and there was no time to prepare it thoroughly if the planting was not to be carried out too late in the season. The grass paddock obtained for the purpose was cleared about fifteen years ago, but had never been cultivated. This was the first time it had been broken up, and the potatoes were simply planted in the furrow made by the plough and then covered over with the soil. It was the usual gray soil, common in the district, and the nearest planted potatoes were fully half-a-mile distant.

The blighted potatoes used for the experiment were very bad indeed, and had been sent to the destructor. Over one acre was planted altogether on 7th November, 1910, with blighted potatoes heated and unheated, and the "seed" was of such a nature that no one would ever dream of planting it, except for experimental purposes. There was only a strip of land six feet wide separating the two plots, and this was planted with rye which, however, grew very thin. It was intended to have a dense, close growth to prevent the spores from the untreated plot reaching the other, but as it turned out it was no protection at all. The plots were examined on 27th January, when the plants were in flower and the tubers forming. Both the heated and unheated seed potatoes produced luxuriant tops, the plants all appeared quite healthy, and at this stage there was not the slightest external sign of blight.

The blight was first visible on the leaves on 21st February, and a thorough examination of the rows on 27th February showed that every plant was affected more or less on both the plots grown from heated and unheated seed. The plants were still green, but the leaves in every case were producing abundance of spores, and sometimes the stems as well. The tubers were also examined, but no trace of blight was found. Hundreds of kangaroo apple plants (*Solanum aviculare*) had grown up among the potatoes, and they had evidently been infected with wind-borne spores, for almost every one was blighted, and the leaves, stems, and young tops bore abundant fructification. (Fig. 119.)

Unfortunately this experiment on a commercial scale, as far as the effect of heating blighted tubers is concerned, is inconclusive, since the plot grown from heated seed could easily be infected by spores from the adjoining crop grown from diseased seed, and the farmer informs me that the prevailing wind is from the unheated towards the plot grown from heated seed.

It will be necessary therefore to repeat the experiment at next planting season, growing the heated seed in some isolated spot where there is no possibility of infection from outside sources, just as it would be in a district where all the "seed" potatoes were either clean, or all were treated to destroy the spawn of the fungus inside the tuber.

I am indebted to Mr. Cornall for the rainfall at Kardella. He has recorded the average for 23 years, which varies from the lowest, 35·70 inches in 1908, to the highest, 59·56 inches in 1889. The rainfall for the six months covering the period of planting and growth of the potatoes up to the end of April is:—

November	..	..	3·85 inches
December	..	..	4·39 inches
January	..	..	1·02 inches
February	..	..	3·86 inches
March	..	..	7·21 inches
April	..	..	3·22 inches

The nature of the season during this period was beau-ideal for the blight, being thundery, showery, and steamy. The official remarks are:—"Much more thunder than the past few years, with muggy atmosphere, cool periods, and very little dry and clear hot weather."

It has been suggested that seed potatoes might be exposed to the natural heat of the sun instead of being subjected to artificial heat, but it will be evident that the temperature cannot be regulated under these circumstances, so as to prevent it rising too high and thereby possibly interfering with their growth.

As already pointed out, the only known means of stamping out or exterminating the Potato Blight in a district is by means of dry-heating the seed potatoes to a temperature of not less than 120 degrees Fahr. for four hours. This heat does not destroy the growing power of the potato, while it kills the spawn inside, as has been proved by experiments several times repeated. If the system is to be a success, it would be necessary to heat all the seed potatoes for a potato-growing area, because the wind-borne spores might infect an otherwise healthy crop, as at Kardella, and of course they should be planted in fresh ground so that self-sown potatoes would not appear.

As regards the arrangements for heating, I am informed by Mr. W. French, Engineer-in-charge at the Doncaster Cool Stores, that the mechanical difficulties could be overcome by placing electric radiators in a special room, so that they would distribute the heat evenly, and the uniformity of the temperature could be controlled. With two adjoining rooms thus fitted up and provided with movable trays all round, the potatoes could be heated and cooled down in the one, while the other was being heated up.

#### CONSTITUENTS OF THE POTATO.

The most important constituent of the potato is starch, which may reach a percentage of 18 to 20 in the best varieties, and the water content on an average is about 75 per cent. In order that the potato may sprout or germinate, this insoluble starch must be converted into soluble sugar, and the ferment or enzyme which produces this change is known as *diastase*.

It is interesting to observe that while the healthy tissue of the potato is acid, the brown tissue permeated by the mycelium of *P. infestans* is alkaline, as well as the scab on the surface. In the internal or brown fleck, however, the brown tissue is acid, like the normal.

Before any practical steps can be taken in the treatment of seed potatoes by means of dry heat for the preventing of blight, it is necessary not only to know the heat required and the time it must act to destroy the spawn of the fungus in the potato, but also the effect of different temperatures on diastase, for if that is destroyed the potato will not grow. In Jost's *Plant Physiology* (1907) the latest results are given as follows :—" At 0 degrees C. the dissolving action of diastase on starch is scarcely noticeable ; an increase in temperature is followed by a rapid increase in its activity, until at 50 degrees C. (122 degrees Fahr.) it reaches a maximum maintained till 63 degrees C. (145 degrees Fahr.) is reached ; if it be heated still further, the activity of diastase again decreases, until finally, at about 85 degrees C. (185 degrees Fahr.) its power becomes destroyed."

It is found by experiment in the field that the potato still grows freely after being subjected to a dry heat of 120-130 degrees Fahr., and this is the temperature which stimulates the diastase to its greatest activity.

The loss of moisture in potatoes so heated was carefully tested by Mr. Scott, Chemist to the Agricultural Department.

Six potatoes were selected and weighed before heating, and the same were then heated to 120 degrees Fahr. for four hours, with the following results :—

—				Before Heating.	Heated to 120° F. for 4 hours.	Loss due to Heating.
1	..	..	..	52·2500 grams	51·7745 grams	·4755 grams
2	..	..	..	48·3500 "	47·7530 "	·5970 "
3	..	..	..	51·1300 "	50·6425 "	·4875 "
4	..	..	..	51·8650 "	51·3360 "	·5290 "
5	..	..	..	41·2310 "	40·8275 "	·4035 "
6	..	..	..	53·4915 "	52·9550 "	·5365 "
Total .. ..				298·3175 grams	295·2885 grams	3·0290 grams

The average loss of moisture from the heating process was about half a gram for each potato, and when six potatoes were pulped they yielded 77·7 per cent of moisture.

(Plates I., II., III., IV., V., VI., XXXII., XXXIII., XXXIV., XXXV., XXXVI., XXXVII., XXXVIII.)

## II.—EARLY BLIGHT, OR LEAF SPOT.

(*Alternaria solani* (E. and M.) Jones and Grout = *Macrosporium tomato* Cooke.)

This is a disease which affects the leaves and stems of the potato, and is generally known as Early Blight, because it appears just when the tubers are beginning to form, or even earlier if the conditions are unfavorable to healthy growth, in contrast to the late or Irish Blight, which does not usually appear until comparatively late in the season. The names, however, do not hold good under our conditions, for the so-called early and late blights may attack the potato at the same time. Leaf-spot is a more expressive name, as it indicates the appearance presented by the leaves when the disease is present, and since the affected leaves often curl inwardly, the term leaf-curl is also applied to it.

The disease first came under my notice in South Gippsland in April, 1896, and now it is very common and the cause of serious loss. It is widely distributed in the United States, where the cause was first definitely determined in 1891, and is also well-known in Europe and New Zealand. It is also known in India where, however, it does not seem to do much damage, according to Dr. Butler, Cryptogamic Botanist to the Government of India, who writes:—"In India there is no indication at present of its becoming a dangerous pest, though I have on many occasions found it hastening the destruction wrought by *Phytophthora*."

## SYMPTOMS OF THE DISEASE.

There is no mistaking this disease when fully developed, although it might possibly be confounded with early maturity and thus escape notice. The stems are hard and woody and of an unhealthy hue, and the leaves are brown and withered, somewhat of the colour of tobacco. Owing to this the entire plant finally withers and dies before its proper season, thus causing the tubers to be small, only one-half or one-third their usual size.

The plants may be attacked very early in the season when quite young, or they may be nearly full-grown before showing the effects of the disease. The premature decay and death of the leaves prevent the tubers reaching their full size, although their number and size will naturally depend on the time and extent of the attack. As they are unripe and imperfectly developed, they are rather soft and leathery in the skin, and will not keep, and for cooking purposes they are deficient in starch.

When the disease is followed from its earliest stages it is found that the leaves have dark-brown, well-defined, rather irregular spots, which increase in number and size until they overrun the entire leaf and destroy it (Figs. 20, 21). If the irregular spots are closely examined they are found to be usually marked by concentric rings, which indicate the stages of growth in the spreading of the spot. Ultimately the leaves become wholly brown on their upper surface, although the under surface may retain more or less of a green tinge, and the brittle, irregularly circular spots often fall out, leaving holes (as in Fig. 20). The stalks are also of a sickly yellow, instead of a bright, healthy green, and latterly lose their succulence, becoming dry.

Although the disease is most noticeable in the leaves which it causes to "curl," it usually attacks the stem close to the ground and gradually reaches the leaves. The stem, as well as the leaves, may thus become involved, and the whole plant die down.



## CONDITIONS FAVOURING THE DISEASE.

While closely investigating the disease at Leongatha I found that every kind of potato was affected, whether grown in virgin land or not, and irrespective of being grown in any of the three classes of soil found in the district—chocolate, gray loam, or black loam, the latter being situated near the creeks. The average rainfall is about 40 inches, so that there is abundance of moisture, and it was noticeable that the diseased plants produced no fruit, or plums, as they are called. But the humid conditions necessary for the rapid development of the Irish potato blight are not required here, as this disease can thrive in comparatively dry weather, and in what are considered dry districts. It is also very much in evidence upon light, sandy soils. Whatever tends to weaken the growing plant, whether poor “seed” to begin with, or faulty cultivation or lack of sufficient nourishment in the soil, makes it an easier prey to the fungus which sets up the disease.

## FUNGUS CAUSING THE DISEASE.

If one of the spots is examined under the microscope it is found to be permeated by fungus filaments, which cause the decay of the tissue, and from these, dark-brown filaments with transverse partitions project and bear the reproductive bodies. The spots are produced by the fungus filaments, which spread from a centre and absorb the substance of the leaf, until sooner or later all the leaves are affected and finally wither away. When the fungus has used up all the nutritive material available, then it prepares for propagating itself. The filaments which spring from the surface are called conidiophores or conidia-bearers, because they give rise at their free ends to *conidia*, as the reproductive bodies are termed. Each brown conidium consists of a number of compartments divided lengthwise and crosswise, and terminates in an elongated, slender, colorless, tapering beak, with cross partitions, the beak being single, double, or treble. (Figs. 23, 24, 25.) The conidium may directly produce on its beak a short conidiophore (Fig. 26), which in turn bears a conidium, and in this way chains of conidia are produced. Or the single terminal beak itself may become a conidiophore bearing a conidium (Fig. 27). In addition to this, each of the numerous segments of the conidium may germinate and very soon produce fresh conidia (Figs. 29, 30), so that in a very short period of time innumerable conidia are produced, and there is no danger of the supply falling short. When ripe these conidia readily fall away, and are carried by the slightest breath of wind to fresh leaves, where under the influence of moisture they soon begin to germinate. When a conidium reaches a moist spot on a leaf, the various cells composing it put forth delicate filaments which enter the stomata, or breathing pores, and safe inside produce the mass of filaments from which fresh conidiophores soon arise (as shown in Fig. 22). It can easily be understood how the fungus spreads, and on the dewy leaf reproduces itself with amazing rapidity.

*Alternaria* is regarded as a “weak parasite,” that is to say, it cannot gain a footing and produce much injury unless the vitality of the plant is lowered from some other cause. Then, when once the mycelium has reached the tuber, it will “hibernate,” as in the case of Irish Blight. Hence everything which tends to produce a healthy and vigorous crop, such as well-selected “seed” from a clean district, deep ploughing, manure where necessary, and thorough tillage, will increase the resistant power of the plant and lessen its liability to this disease.

## HIBERNATING MYCELIUM.

It has been experimentally proved by Massee that the mycelium of the fungus winters in the tubers, although there is no discoloration of the tissues, as in the case of potato blight. The consequence is that the disease may be transmitted from one generation to another by means of this latent mycelium, and the tubers used as "seed" from a diseased plant may show no evident indications of being affected. This shows how important it is to select the "seed" when the tubers are being dug, so that only the progeny from healthy plants may be used. How often is the best of the crop sent to market and the culls used for "seed."

## HOST-PLANTS.

This fungus not only attacks the potato, but also the tomato, when it is generally known as "Black Rot." This name was given to the disease from the fact that it was first observed on the fruit, where it forms dark-coloured patches, either at the blossom end or stalk end, or even on any part of it where there is a puncture of the skin sufficient to admit the germ-tube of the conidium. But it also occurs on the leaves, where the spots usually begin as minute dots, and as they enlarge form large blotches with concentric markings, as in the potato. In this stage it is known as "rust," and when later in the season it attacks the stems it is called by tomato growers, "black spot." They are different stages of the same disease, however, and in each case the conidia are produced in immense numbers and readily disseminated. That it is the same fungus, although under different names, which produces the disease in the potato and the tomato has been shown by Massee, who has repeatedly produced the disease on tomatoes by inoculation with spores produced on a potato-plant, and *vice versa*. It would be an additional check on the identity of the fungus to find out if it produced its conidia in chains, as in the potato, and was therefore an *Alternaria*. On carefully microscopically examining specimens from the tomato, I found conidia attached in chains of two or three (as shown on the potato in Plate VIII.), so that the *Macrosporium tomato* of Cooke is really the same fungus as that on the potato. It has also been found here on the Black Nightshade (*Solanum nigrum*) As in the potato, the spots on the leaves have concentric rings, and on the stem there are large blotches forming black strips and causing its decay.

## TREATMENT.

It is satisfactory to note that growers themselves, as the result of dear-bought experience, have arrived at a means of coping with this disease. In seeking to account for it, the only explanation they could offer was that the "seed" had run out, and the evident remedy to get new "seed" from another district. It is not considered safe to plant the same potato "seed" for more than two seasons, and even in the second season there may be a considerable loss, even as much as 20 per cent. I personally examined a number of fields under similar conditions, and found considerable variation. In one field, which produced six tons of good sound tubers the previous season, in the following year the growth was very unsatisfactory, as from their first appearance above ground the tops were weak and sickly, and a number never came up at all. In an adjoining paddock, where the soil was similar, and the new seed potatoes planted the same week, and for the first time, the produce was at the rate of 11 tons per acre without misses, and the plants all strong and healthy. It is not only necessary to have fresh "seed," but to adopt a rotation as well, and although the growers had no idea as to why these measures were useful in checking the disease, it becomes apparent when the cause of it is considered.

From the nature and mode of life of the fungus causing the disease, and from the experience of growers, the following recommendations may be made :—

1. Select clean “seed” from a healthy crop grown in a district free from the disease.
2. Do not plant potatoes in succession in the same paddock, as the disease is thereby encouraged and perpetuated. It has been observed that where the disease already existed, it is much worse in the year following if potatoes are planted there.
3. High cultivation and all that it includes will lessen the liability to attack.
4. All tops should be burned that have shown the least traces of infection as the conidia and spawn live through the winter on such refuse.
5. Tomatoes should not follow a diseased crop of potatoes, or the reverse.
6. Spray with Bordeaux mixture or copper-soda solution, as recommended for Irish potato blight. This must be done early, as the grower must anticipate the attack and not wait until he sees the plants succumbing to the disease. In the United States of America, where the disease seems to be worse than in other countries, spraying has been successfully and extensively adopted, and it has been found there that spraying at the rate of 100 gallons per acre gave better results than 50 gallons per acre.
7. Since the mycelium of the fungus winters in the tubers, it will probably be found that heat destroys it, as in the case of Irish Blight.

(Plates VII., VIII.)

### III.—RHIZOCTONIA ROT, OR POTATO COLLAR FUNGUS.

*Hypochmus solani* Prill. and Del. = *Rhizoctonia solani* (Kuehn) — *Corticium vagum* var. *solani* Burt.)

On very young potatoes it is quite a common occurrence to see them more or less covered with what looks like little specks of adhering dirt (Fig. 58), and delicate brownish threads spreading between them like a cobweb. On full-grown potatoes, and very often on those sold for "seed," there is the same appearance, but only more pronounced, the specks being a little larger, something like small shot, and the grower tells you, when his attention is called to them, that they are only little particles of manure sticking to the potato. (Plate IX.) When you try to rub them off, however, they still remain, and if you wet such a potato the spots stand out quite black. Very often they can be scraped off with the finger-nail, as they scarcely penetrate into the skin, and they are generally considered of no particular importance. But, as we shall see immediately, these little specks develop, under suitable conditions, into a fungus, which may either cause the tubers themselves to rot, or the young potato plants to decay at the "collar" and die right off. (Plate XI.) This fungus is just another illustration of what is so commonly met with in fungus diseases, of the small beginnings which are entirely overlooked and neglected by the so-called practical man, and show "what great events from little causes spring."

Rhizoctonia, which literally means root-destroyer, is the name given to one stage of this fungus, which is usually confined to the underground parts of plants. It is found on quite a variety of roots and tubers, and was first discovered by De Candolle in 1815 attacking the roots of lucerne and clover and the corms, or underground stems, of the crocus. As early as 1858, it was observed by Kuehn on potatoes in Germany, producing what he called the "pock disease" on the tuber, because it appears on the skin of the potato in the form of minute dark-brown pustules. It is now known to be very widely distributed, being found in America, Europe and New Zealand, and for some years past it has been noted by myself in Australia. It is now becoming very prevalent, as it has hitherto been allowed to spread and multiply without any effort being made to check it. In fact it is not regarded as of any consequence by the majority of growers, and seed potatoes with the pustules are freely planted.

In order to warn growers against the dangers of using such seed potatoes, and to enable them to understand the nature and cause of the disease, a full and illustrated account is here given.

#### HOST-PLANTS AND PARTS AFFECTED.

Just as the Irish Blight does not confine itself to the potato, but is found on quite a number of plants, so this disease has been met with on the most varied economic plants, as well as on such ornamental plants as the carnation and violet. It has been recorded on the sugar beet as well as the potato, lucerne and clovers, carrot and celery, cabbage, cauliflower, and radish, lettuce and rhubarb. It may not be the same species of the fungus in every instance, capable of passing from one plant to the other and infecting it, for experiments in cross-inoculation would be necessary to settle that point.

The parts visibly affected vary in different plants. In the potato it may cause rotting of the tubers, so as to give rise to an appearance resembling brown rust. (Plate X.) It may also cause a stem rot just at or below the surface of the soil, also involving the slender roots (Fig. 120), and a disease



known as "Rosette" (Plate XL.), in which the leaves are all clustered together, owing to the normal growth being checked. In the beet, carrot, radish, and turnip it causes a root-rot; in the cabbage, cauliflower, and celery a decay of the young seedlings; in the lettuce and rhubarb a leaf-rot, and in the lucerne and clovers the roots are attacked, causing the death of the parts above ground.

In Australia, so far I have only found rhizoctonia on the potato-plant, and it was first described in Victoria in March, 1903, and on the turnip in May, 1911.

#### CAUSE OF THE DISEASE.

The fungus causing this disease requires to be studied before the symptoms produced by it can be understood, and the life-history of it, as it occurs on the potato, will be dealt with here. There are at least three well-marked stages in its history—the resting, the vegetative, and the reproductive—and because the first is the only one which has hitherto forced itself upon the notice of the grower, the importance of the fungus as a whole has been very much underrated.

##### 1. *Sclerotium, or Resting Stage.*

The resting or dormant stage appears usually on the tuber itself, also on the stems and rootlets in the form of numerous brown, rust-coloured patches, which, on account of their minute size, may easily be overlooked or mistaken for something else. On wetting such a potato these patches become quite black, and are then quite conspicuous from the way in which they stand out in contrast to the skin of the potato. (Plate IX.)

They vary in size from that of a pin-head to nearly half-an-inch in diameter, and may be almost round, but are usually irregular in outline, sometimes forming streaks up to one-fifth of an inch in length. The external appearance is thus quite distinct, and when one of these patches is examined under the microscope it is equally so.

Each patch consists of a dense mass of interwoven fungus filaments or *hyphae*, and the whole constitutes the *mycelium*. (Figs. 36, 37.) These fungus threads, which at first are white, but ultimately become a deep chestnut brown, are composed of numerous branching joints or segments, each of which is usually different from its neighbour, and the filaments consist of characteristic enlargements, which render them readily distinguishable from the filaments of other fungi. (Fig. 36.) They are short and stout, and exceedingly variable in shape. They may be connected together in lines, or form elbow-like projections at the sides, from which other joints arise, and so on, until a dense tangled mass arises, constituting the compact dark-coloured growth seen with the naked eye. If an affected potato is kept moist under a bell jar, this dormant mycelium starts into active growth and produces long, white, straight, regularly-jointed filaments, which ultimately become brown and enable the fungus to spread in the moist earth and thus infect other tubers.

These densely compacted, dark-coloured masses of hyphae, in a resting state on the surface of the potato, are known as *sclerotia*, or hard bodies, and they serve to carry over the fungus from one season to another, being able from their firm texture and compactness, to withstand adverse conditions, which might prove fatal to the individual strands composing them. These bodies are not uncommon in various groups of fungi, and they vary in size from grains of powder to that of a cricket ball, or even a child's head, as in the case of native bread, or they may be elongated and cylindrical, as in the well-known instance of ergot of rye.

In the case of the potato-plant, they may either be returned to the soil when the stem decays, or they may remain firmly attached to the tuber. When such tubers are used for seed, the young sprouts are sometimes attacked by the fungus, and the young and tender plants may become rotten just at or below the surface of the ground. (Plate XI.) Experiments with diseased and healthy potatoes show that infected tubers produce a diseased crop, while clean "seed" in clean soil will produce a clean crop.

The sclerotia are produced on the skin of the potato by the brown filaments spreading over the surface like a fine cobweb. These concentrate at a point and wrap themselves tightly round each other, so as to form a hard compact body, or sclerotium. They are thus formed on the surface and the tuber is absolutely sound beneath. In some cases, however, the sclerotia are formed in the tissues, and they have been found at least half-an-inch beneath the surface of the skin.

Although generally formed at the surface of the tuber, so that they can be scratched off with the finger nail, and leave the skin beneath uninjured, yet they may develop filaments and penetrate inside. If sections of such specimens are made, the fungus filaments are seen beneath the skin, causing the tissue to become brown and decayed in irregular patches to a greater or less depth.

When the pustules are numerous and generally producing filaments inside the potato, the decay of the flesh of the potato is very general and extends inwards. The result is that there is a zone of decayed tissue beneath the skin which may ultimately involve the whole of the potato. I have shown two sections of diseased potatoes, the one being due to *rhizoctonia* (Plate X.), and the other to *phytophthora*, or Irish Blight (Plate II.) These sections are of special interest, because both represent the disease known in Tasmania as "brown rust," and it is seen that similar appearances may be due to different fungi. In fact, Plate X. represents a section of the potato sent to me from Tasmania at the beginning of the potato trouble as a typical specimen of "brown rust," and although, generally speaking, this disease is caused by *phytophthora*, yet in this particular instance it was due to *rhizoctonia*, and no Irish Blight fungus appeared on the specimen kept under a bell jar, even although it was critically examined daily up to the thirty-third day. I had an opportunity of examining numerous specimens of diseased potatoes brought by myself from Tasmania, and found *rhizoctonia* very common, giving rise in many instances to the browning of the tissue beneath the skin, known as "brown rust." This example also proves my contention that from a naked eye examination of the tuber alone, unless the Irish Blight fungus is developed on the surface, it is impossible to tell without a microscopic examination whether the internal browning of the tissue is due to *rhizoctonia* or *phytophthora*.

I have found *rhizoctonia* associated with *phytophthora* in some cases, but in others *rhizoctonia* alone has produced a similar effect on the potato.

In connexion with sclerotia on the stem, not only were there numerous fungus filaments creeping on the surface, but the tissue inside the stem and outside the vessels was permeated by them. Young tubers about a quarter of an inch in diameter attached to diseased stems, even at that early stage showed the sclerotia beginning to form. On the slender roots the sclerotia were also plentiful. A clear case of the fungus filaments passing from the sclerotia on the tuber used as seed to the plant produced, was observed at the Experiment Farm at Cheltenham. The old "set" was found with the sclerotia upon it. These germinated and the filaments produced entered the young shoot, so that when the tubers were forming the filaments passed out to them. The young tubers were found covered with the brown net-work,

and the filaments were most plentiful at first towards the stalk end, whence they spread all over.

The course of the fungus is easily traced. The filaments extend along the underground branches, or rhizomes, and when the tubers are being formed laterally or terminally, they pass on to them, covering them at a very early age with the spider-web-like brown filaments. Sclerotia may be formed very rapidly by the converging brown filaments, as they have been found on young tubers when about the size of peas.

## 2. Vegetative Stage.

When a potato with sclerotia and the brown cobweb-like filaments is kept moist under a bell-jar, in the course of a day or two luxuriant colorless hyphae are developed from all the sclerotia, and also from the spider-web hyphae. The colorless hyphae may either penetrate the skin of the potato and produce an internal mycelium, or they may attack the young sprouts when they begin to grow.

When the mycelium attacks the young shoots it produces two kinds of hyphae. One kind reaches the inner tissues, is colorless, and, if luxuriant, produces a wet rot, which results in the death of the young plant. Another kind is dark-colored, and grows on the outside of the young stems and roots, and sometimes forms a felt-like covering which girdles the stem and causes the bark to peel off. When this felted mycelium, which may be detached in sheets from the stem, reaches the surface of the ground, it prepares for the formation of spores. A luxuriant, fragile, mealy, white growth surrounds the stem, but does not penetrate it, and as soon as the spores are matured, it dwindles away and disappears. This is the reproductive stage. It is very evanescent, generally appearing after rain and soon drying up.

## 3. *Hypochnus*, or Reproductive Stage.

Up till 1903 no form of fructification had been discovered in connexion with rhizoctonia, and it was previously considered to be one of the sterile fungi. The sclerotia on the tubers, stems, and roots enabled the fungus to be perpetuated from one season to another, but no spores were produced. In that year, however, F. M. Rolfs, of the Colorado Experiment Station, found the spores, and from the nature and mode of formation of these reproductive bodies, was able to assign a systematic position to the fungus.

Before this, in 1891, Prillieux and Delacroix, described a fungus found at the collar of the stem of a growing potato as *Hypochnus solani*, which was evidently the same. Then a similar fungus was brought under my notice in January, 1910, by Mr. Seymour, potato expert. Specimens of potato-plants were forwarded to me which had rotted at the "collar," and a profuse development of a white mould appeared just above the surface of the ground. This was found to consist of a net-work of filaments connected by cross branches, and producing short branches at the extremity, the end cells of which became enlarged and swollen. From these swollen cells slender projections arose, varying in number from two to six, and at the end of each the hyaline ovoid spores were formed. (Fig. 43.) This was the spore-bearing form of the fungus, and this layer is very delicate and soon dries up. The spores readily fall away, and probably serve for the rapid multiplication of the fungus in its vegetative condition. The name of *Corticium vagum* var. *solani* Burt. has also been given to this fungus, but the spore-bearing layer is not compact, as in that genus. By whatever name it is known, there is no doubt of its connexion with the filaments of the rhizoctonia stage. It is convenient to speak of the three stages of the fungus as if they were distinct, although



they all belong to one and the same species. As the reproductive stage is considered to be the highest form of the fungus, it is recognised as the one which affords the most reliable character for naming, so it is classified as *Hypochnus solani*.

#### EFFECTS OF THE FUNGUS.

The most noticeable effect is the numerous minute dark-colored patches on the surface of the tuber, but this is not regarded as of any serious consequence. It is seen to be of supreme importance, however, when it is found that it is through the tubers the fungus is introduced into the young plant, as well as into the soil. The stems of the young potato-plants are often rotted either at the collar or beneath the soil, and they soon die by what appears to be a sort of wet rot. In some cases the fungus simply causes the bark to peel off right round the stem, and this girdling or cincturing of the stem makes the tops more luxuriant, while the tubers are either not formed at all or they are small, owing to the sap from above not returning to nourish them. As a result of this, small green potatoes are sometimes formed on the stem above the point of injury.

Potato-tops are often conspicuous in the field with wilted leaves, which sometimes assume a purplish colour, and the stems may be swollen at the nodes, or where the leaves arise. I have found this appearance associated with rhizoctonia, and in some instances the leaves had likewise the characteristic blotches due to potato blight.

There is also a "rosette" development of the tops, in which there is excessive branching, and these branches with their terminal leaves are clustered together to form a bunch. It is not at all uncommon in some potato crops to find a plant here and there with luxuriant foliage, but the top portion wilted and shrivelled and curled up, so that it stands out quite conspicuous among the normal plants. The specimen photographed (Plate XL.) was taken from a field of potatoes in March, 1911, and the peculiar appearance was attributed to the Rutherglen bug and other causes. On examining such a plant below the foliage, the stem is seen to be densely coated with a white mould, rising from the collar upwards, completely surrounding the stem, extending to the branches, and even to the under surface of the leaves. There are usually small potatoes developed in the axils of the leaves above ground accompanying this abnormal development. The white mould was also found coating these aerial potatoes, and in some instances they were affected with the blight, which had probably been produced by the spores falling upon them from the diseased foliage. (Plate XL.) The tubers underground may be larger or smaller, according to the stage of attack, and the extent of injury by the fungus.

If the attack is early the young shoots droop and die, and sometimes there is a loss of one-fourth to one-third of the crop from this cause. But if the attack is late, the plant produces the aerial tubers in greater or less abundance, and the underground tubers are few, generally small and unmarketable.

#### CONDITIONS FAVOURING THE DISEASE.

We have no exact knowledge of the conditions which favour the development of the fungus. An excess of moisture in the soil, and the presence of freshly-decaying matter will tend to render it more luxuriant. It is found that the fungus thrives well in a sour soil, and therefore liming will be beneficial, but it does not entirely prevent it. It is suspected that the sclerotia may develop on the roots of weeds, so that clean cultivation and everything which promotes good sanitary conditions will render the potato-plants more resistant.



# DISTRIBUTION.

This disease of the potato is known in Europe and the United States of America as doing considerable damage. It was observed in Germany as early as 1858, and it existed in Iowa in 1890. It has also been known in New Zealand for some years, and Kirk reports it in 1908 as the cause of extensive potato failures in the early part of the season. In Australia it was first discovered in March, 1903, when I found it on some potatoes sent from Castlemaine, Victoria. It is now known in Victoria, New South Wales, Queensland, South Australia, and Tasmania. I have just received (19th June, 1911) specimens of young potato-plants affected with the fungus, from West Australia, so that it occurs in all the States.

# TREATMENT.

Various experiments were carried out with the sclerotia, or "black speck scab" as it is called, in order to discover some means of destroying the vitality of the fungus. Heating to 120 degrees Fahr., as for Irish Blight, did not destroy it, nor the ordinary steeping in formalin, but corrosive sublimate was effective.

A potato with numerous sclerotia was steeped in a solution of corrosive sublimate (2½ ozs. to 15 gallons of water) for two hours. It was afterwards dried, and two sclerotia were removed with a portion of skin, and placed on a glass slide over water. The potato was placed on damp earth in a jar and covered. No sign of germination or growth from the sclerotia or the spider-web hyphae on the potato appeared after several days.

Formalin was used at the rate of 1 lb. to 40 gallons of water in an exactly similar manner, and next day there was luxuriant growth both from the sclerotia on the slide and the hyphae on the potato.

A potato with sclerotia was used as a check and placed on damp earth in a jar. In two days there was luxuriant growth from all the sclerotia and from the hyphae on the surface of the skin.

A field test was also conducted at Burnley Horticultural Gardens, where 28 rows of potatoes were planted badly affected with sclerotia, and they were treated in various ways as shown in table V. Corrosive sublimate was again the most successful, only one per cent. being affected in some instances.

But the simplest and most effective method is to use clean "seed," and this is not a difficult matter since the sclerotia are so conspicuous on the skin of the potato. Clean "seed" in clean soil will produce a clean crop.

Not only is it necessary to use clean "seed," but the fungus may be in the soil from a previous crop, and so potatoes must not be planted in the same ground year after year. This rotation of crops is absolutely necessary for healthy growth, and it is the constant planting of diseased "seed" in the same soil that has made rhizoctonia so common that it is difficult to get "seed" of some varieties free from it.

Whenever a parasitic fungus occurs in the soil, particularly in the form of sclerotia, it is no easy matter to deal with on a large scale. Salmon, however, has found that by applying phenol, or carbolic acid, the sclerotia present in the soil are rendered harmless. He used 1 oz. to 1 gallon of water, and the plants grown in the treated soil were not only free from disease, but apparently stimulated in their growth.

All seed potatoes showing the slightest trace of rhizoctonia should be rigorously rejected and rotation of crops practised.

(Plates IX., X., XI., XII., XIII., XVIII., XIX., XXXIX., XL.,  
XLI., XLII., XLIII.)

## IV.—POTATO SCAB.

The term "scab" is applied to quite a number of different kinds of skin trouble, which are due to as many different causes, and since these cannot be determined at a glance, there is a certain convenience in the use of a general term. But when experiments are being conducted for the prevention of scab, it is absolutely necessary to determine the agents at work, and it is want of attention to this which has caused so much confusion as to the effect of different treatments.

Since the study of the diseases of the potato is undertaken with a view to their ultimate treatment, it is necessary to understand clearly the cause and nature of the disease investigated, and also not to be misled by a common name applied erroneously to the disease. In the whole range of plant diseases, there is none to which this remark is more applicable than to scab, and to illustrate this point, the various forms so-called will be briefly dealt with, in addition to a detailed consideration of those commonly met with here.

The mere mention of the names of the varieties of "scab" will show what a difficult and thorny subject it is, and the so-called forms of it will indicate how superficial appearances are often deceptive. The causes assigned are equally variable.

A mechanical irritation of the skin may result in an excessive formation of cork and thus produce what is known as "scab." Bacteria and fungi are likewise concerned in it, and "wire-worms" and "cut-worms" may gnaw away the skin in patches. Even the blisters or galls produced by the "eel-worm" may assume a scabby appearance, and from the point of view of the grower, it is one of the commonest forms of this disease. Amid all this confusion and uncertainty the grower wishes to know how to produce a crop "free from scab," and that is the question which we will now attempt to answer, as far as our present knowledge goes.

## THE HEALTHY SKIN OF THE POTATO.

The skin of the potato is really of the nature of cork, and although it is only a thin layer, it is just as distinct as in the cork oak. When a cross-section is made of a small portion of the skin and magnified under the microscope, it is seen to consist of cork cells. These cells are flattened and arranged in rows one above the other, tier upon tier (as shown in Fig. 44k). Immediately beneath these are the cells containing starch grains (st.).

If the skin of the potato formed an enclosed layer all round, there would be no means provided for the admission of air; but just as in the leaves there are little openings or mouths for the admission of air and other gases, so in the skin of the potato there are little raised openings, or breathing pores. These openings are known as *lenticels*, and at a one is just beginning to be formed. The cells at this spot take in moisture, swell, and cause the skin to burst as at *f*, and the lenticels thus formed are filled with loose, whitish, mealy cells. After a long spell of wet weather these white, mealy cells may grow out and appear at the surface, where they might be mistaken for a mould. (Fig. 150.) Under these conditions the cells at *f* multiply excessively, being pushed up from below, and the outermost cells are thrown off in the form of loose, fluffy material.

The filaments of fungi can enter through the lenticels, and the irritation thus set up may give rise to further growth and the ultimate formation of a "scab." So that even the natural and necessary openings in the skin of the potato may be used for a very different purpose to that originally intended.

As the result of experiments it has been found that the thickness of the skin varies with the amount of moisture, a dry season producing a thinner skin than a season with adequate rainfall, as well as with the kind of manure used.

### TRUE "SCAB."

A true "scab" approaches most nearly to what takes place in animals when a wound is left open and healing takes place under a scab. So in the potato, when a crack is formed or irritation is set up by something corrosive in the soil, or even the pressure of the hard soil against the growing potato, the plant seeks to repair the injury by producing a scab composed of corky cells, just like the skin, only the walls are thickened. Even the tissue of the lenticels, under the influence of excessive moisture, may grow luxuriantly, and the outermost cells are cut off by a corky layer and die. Then the living cells beneath may burst through these dead cells, and cork is again formed with a like result. Rough corky warts or excrescences may thus arise and constitute a scab. In a scab of this nature it is evident we have little power of control; but if the "scabby" appearance is due to some organism which can be destroyed by chemical or other means, then treatment of the seed potatoes is to be recommended. In the great majority of cases known in Australia, the so-called "scab" is the result of an eel-worm, and in a less degree to the fungus known as *rhizoctonia*.

### EXPERIMENTS TO TEST THE CONDITIONS FAVORABLE TO THE PRODUCTION OF "SCAB."

It is commonly stated, without any reservation, that if potatoes are planted where there is plenty of wood ashes or abundance of lime, you are sure to get "scab." Then this statement is sometimes qualified to the effect that this is most likely to occur in stiff soils.

So to answer the question, as far as one season could do it, I planted potatoes at Burnley in loose sandy soil, as well as in stiff clay soil. The seed was obtained from one of our most reputable seedsmen, and selected by Mr. Seymour, potato expert. Beauty of Hebron and Coronation were the varieties chosen. At the Burnley Gardens, through the courtesy of the principal, Mr. E. E. Pescott, I was fortunate in securing the right kind of soil. In the lower orchard there was a patch between the fruit trees of loose sandy soil, and in the upper orchard the soil was stiff and clayey. The loose soil in the lower orchard had been used the previous season for an experimental plot of field peas and various clovers, so that it was an excellent rotation for the potato. The plants were cut level with the ground and removed for weighing, and only the roots were ploughed in. In the clay soil strawberries were planted last year and regularly cultivated, but owing to the lack of moisture they were a failure.

The seed potatoes were planted without manure so as not to interfere with the result, and it was observed that although carefully selected, many of the tubers had the little black bodies on the skin, which show up so clearly when wetted, and are the resting stage of a fungus, known as *rhizoctonia*, or root-destroyer.

Each plot consisted of a single row, in which 50 potatoes were planted, and the corresponding plots of the two varieties were in the same line. The rows were 3 ft. apart, and the potatoes in each row were planted 1 ft. apart. The planting was rather late, taking place on 18th and 20th December, 1909, and the potatoes were all dug on 19th May, 1910.

The accompanying photograph (Plate XX.) of the plots in the loose soil was taken on 6th April, showing the luxuriant growth, and the following table gives all the necessary details:—

TABLE V.—TEST OF CONDITIONS FAVORABLE OR UNFAVORABLE TO THE PRODUCTION OF "SCAB."

No. of Plot.	Variety.	Soil.	Treatment.	Crop.	Diseases.	
					Rhizoctonia.	Other.
1	Coronation	Sandy	.. .. .	lbs. 22	Per cent. 25	Potato moth and cutworm
2	"	"	Wood ashes only ..	62	50	Potato moth
3	"	"	Wood ashes, and tubers treated with formalin	69	70	
4	"	"	Wood ashes, and tubers treated with corrosive sublimate	69	1	Insect wound and one thready eye
5	"	"	Freshly slaked lime only	95	45	One thready eye
6	"	"	Freshly slaked lime, and tubers treated with formalin	108	80	Cutworm in one potato
7	"	"	Freshly slaked lime, and tubers treated with corrosive sublimate	108	25	
8	"	"	Sulphuric acid only ..	115	60	One thready eye
9	"	"	Sulphuric acid, and tubers treated with formalin	117	85	Cutworm
10	"	"	Sulphuric acid, and tubers treated with corrosive sublimate	102	50	
11	Beauty of Hebron	"	.. .. .	21	75	
12	"	"	Wood ashes only ..	25	80	Potato moth
13	"	"	Wood ashes, and tubers treated with formalin	41	85	
14	"	"	Wood ashes, and tubers treated with corrosive sublimate	45	15	
15	"	"	Freshly slaked lime only ..	61	95	
16	"	"	Freshly slaked lime, and tubers treated with formalin	75	60	
17	"	"	Freshly slaked lime, and tubers treated with corrosive sublimate	95	2 potatoes slightly affected	Potato moth
18	"	"	Sulphuric acid only ..	78	75	
19	"	"	Sulphuric acid, and tubers treated with formalin	95	95	
20	"	"	Sulphuric acid, and tubers treated with corrosive sublimate	82	45	Potato moth
21	Coronation	Clay	.. .. .	Potatoes, 6	2 potatoes = 33	Potato moth
22	"	"	Wood ashes only ..	6	1 " = 17	"
23	"	"	Freshly slaked lime only ..	17	6 " = 35	"
24	"	"	Sulphuric acid only ..	4	2 " = 50	"
25	Beauty of Hebron	"	.. .. .	38	27 " = 71	"
26	"	"	Wood ashes only ..	36	9 " = 25	"
27	"	"	Freshly slaked lime only ..	38	28 " = 73	"
28	"	"	Sulphuric acid only ..	25	19 " = 76	"

The yield of potatoes, it will be observed, was very uneven, and in the clayey soil the crop was a comparative failure. In the loose soil plots 1 and 11 gave the smallest yields, because they were planted close to the fruit trees, and not only was their nourishment affected by the roots of the trees, but being in the shade the plants could not manufacture the necessary starch to store away in the tubers.

In the clayey soil the season was so dry that little growth took place, and the result shows clearly how the same varieties planted at the same time, and undersimilar weather conditions, may yield so differently owing to the character of the soil and its capacity for absorbing moisture. The yields were so small that the number of potatoes in each plot is given. In the upper portion, where Beauty of Hebron was planted, the soil was looser and the yields correspondingly larger.



But the object of the experiment was not to test the yield of varieties, only to find out the conditions favourable to the production of "scab," and it may be stated at once that no true "scab" was found in a single potato. Various wounds and scars due to insects were found, such as the cut-worm and grub of the potato moth, and in isolated cases the rhizoctonia produced scars which might be called "scab"; but there was none of that superficial, rough, patchy, or continuous elevation of the skin which is generally regarded as such.

Lime freshly slaked and wood ashes were freely used in the rows, as well as acid, applied by watering the ground just before planting with a solution of one teaspoonful of commercial sulphuric acid in a gallon of water. The seed potatoes were likewise steeped in formalin and corrosive sublimate solution, as recommended for the prevention of "scab," and then planted with acid, lime and wood ashes, but without the production of "scab."

The results of this season's experiments show that "scab" is *not always* produced even in alkaline or acid soil, and that there are other factors controlling its development, such as variety, date of planting, and nature of soil, &c.

The season was practically dry, as the rainfall from the time of planting to that of digging shows:—

December, from 18th to 31st	..	51 points
January .. ..	..	98 points
February .. ..	..	38 points
March .. ..	..	219 points
April .. ..	..	93 points
May, 1st to 19th	..	112 points
Total .. ..	..	6.11 inches

The sclerotial form of rhizoctonia occurred in every plot, more or less, as might have been anticipated from its general occurrence on the seed potatoes used.

#### SO-CALLED "SCAB."

During the last two seasons every form of skin disease affecting the potato in this and some of the neighbouring States has been brought under my notice, with the result that more definite knowledge has been gained as to the causes producing them. I have also personally visited a number of potato-growing districts, and in some of them have inspected every potato-field, so that the disease was observed at different stages. It is not possible in every case to account for the appearances presented, and they are not necessarily due to organisms of any kind; but, speaking generally, they were found to group themselves under the following heads:—

1. *Mechanical causes.*—There were certain blemishes on the skin which were not associated with any evident organism, and may have been due to unsuitable conditions of soil and climate. Thus, when the season is dry and the soil comparatively stiff, the pressure of the growing tuber against the unyielding soil may cause injury. The injured tubers continue to grow, and as the original blemishes expand and become larger and larger, they are surrounded or covered by a thickened layer of wound cork, constituting a "scab." The injury may be slight when it produces merely a corrosion of the skin, or it may extend deeper, according as the adverse conditions affected the tuber early or late in its growth (Fig. 63).

2. *Wire-worms*.—The wire-worm, which is the grub of the click beetle (*Lacra* sp. and others), is very prevalent in light soils and land newly broken up. It gnaws away and perforates the skin of the potato, causing scars or blemishes, which have a "scabby" appearance. In many instances they were actually found on these scars, and on examining the soil in which such potatoes were grown, they occurred in great abundance. This pest does considerable damage to the crop, as it is very voracious and may attack every potato.
3. *False Wire-worms or Millipedes*.—These are often confounded with the true wire-worm, although they are quite distinct, and from the large number of feet they possess, they are popularly called "thousand feet." They are closely allied to insects, and different species of *Julus* disfigure the potato (as shown in Fig. 65). They were not met with so frequently as the former.
4. *Cut-worms*.—In some instances there were abrasions of the skin found associated with the cut-worm, and the soil in which the tubers grew contained them in abundance. They also eat into the potato and produce unsightly scars. I am indebted to Mr. C. French, jun., for the names of the following genera of cut-worms which attack the potato:—*Agrotis*, *Leucania*, *Heliothis*, and *Mamestra* (climbing cut-worm).
5. *Potato Moth*.—This moth (*Lita solanella*) is very common in some seasons, and the grub produces the well-known tunneling of the potato; but in some cases there were black, warty excrescences at the "eyes," which were traced to this moth (Fig. 57).
6. *Potato Eel-worm*.—In its typical form it produces blisters or galls, which can only form when the potato is growing, and is readily recognised; but the blisters may be broken and form rough patches, or the eel-worm may affect the tuber at different stages of its growth, so that all sorts of abrasions and excrescences result. In all the leading districts where potatoes are grown the eel-worm has been found, and I have no hesitation in saying that it is the main cause of the so-called "scab." Hence, from the point of view of the practical grower, as well as that of the plant pathologist, it is that form of skin disease which causes the greatest annual loss, and the discovery of measures of prevention will be of immense benefit to the potato industry. While the eel-worm is so generally distributed, there is one notable exception as to the kind of soil in which it occurs. In the dried-up swamps consisting of peaty soils, such as are found in the Portland, Tynong, and other districts, and which will readily burn when a light is applied to them, I have never come across a "blistered" potato. But in the dark sandy soils surrounding and adjoining these dried-up swamps a little higher up, such potatoes are quite common. There is something in a peaty soil which is uncongenial to the eel-worm, and it suggested to me that it would be a very useful experiment to test the effect on the eel-worm of applying a dressing of such soils to the onion-growing land of Portarlington and elsewhere. At any rate, the potato eel-worm does not thrive in soils of a peaty nature.

7. *Scab and Oospora scabies*.—On the surface of “scabby” potatoes, when freshly dug, I have often found a delicate greyish mould which is very evanescent. It soon dries up and disappears on exposure to the air, and in order to get specimens for microscopic examination, it is necessary to convey the diseased tubers embedded in the soil. When a small portion of this delicate grey mould is examined under the microscope, it is found to consist of very slender hyaline filaments, generally curved in various ways, branching slightly, and sometimes apparently septate. The aerial hyphae quite agree with the description of “breaking up into bacteria-like segments, after producing spirillum-like ‘spores’ by the coiling of their free extremities” (Fig. 127).

The description fits exactly that of *Oospora scabies*, but I cannot accept this fungus as being the main cause of the scabby appearance, since these tubers were found swarming with “eel-worm,” which were invariably present, even in the early stages of the scab. Thaxter has shown that a form of scab may be produced by the fungus (Fig. 64), but in Victoria, at least, the symptoms are so pronounced, and the breaking of the “blister” is so evident, that we cannot dismiss the eel-worm as a mere secondary cause. It is not unusual in “scabby” potatoes to find the “blister” merging into the “scab,” and when potatoes with blister were planted and produced only scabby tubers, the connexion between the two is all but proved. This fungus was also found associated with rhizoctonia scab (Plate XLIII.), so that it has never been found here as an independent fungus causing “scab.”

It may also be noted that I have found “blister” and “blight” together in the same potato, so that the presence of the one does not exclude the other.

I have found *Oospora scabies* common enough on potatoes, but not under conditions to suggest that it was always the primary cause of the “scab.” It occurs on a roughened skin as well as on broken blisters produced by eel-worm, and since these also occur without *Oospora* being present, it cannot be considered the cause under these circumstances.

There are several very destructive fungi in other countries associated with “scab,” but fortunately they have not yet been introduced here. Bacteria have also been found, but their connexion with the “scab” has not been definitely settled. In the United States, in 1890, Bolley found bacteria associated with the “scabby” tissue on the skin of the potato, and he successfully carried out infection experiments with a specific bacterium which was isolated. The diseases caused by insects or millipedes are dealt with by my colleague, Mr. French, so that no further reference is made to them here.

#### “SCAB” IN AUSTRALIA.

For a number of years growers have recognised a skin disease which disfigured the potatoes, and was generally known as “scab.” Inspectors under the Vegetation Diseases Act likewise condemned them as such, and naturally there was a desire for information as to the nature of this disease in order to prevent it if possible. It was generally attributed to a fungus, which is

a common cause of "scab" in America, and known as *Oospora scabies*; but the fungus has only been found here on broken blisters, and cannot be regarded as a primary cause. In the great majority of cases such potatoes showed the presence of the eel-worm, and the "scabby" appearance was mainly due to this cause.

### I. POTATO BLISTER AND "SCAB."

The disease caused by the eel-worm on the surface of the potato is generally known as "blister," because the eel-worms cause little galls or swellings to be formed on the surface (as in Fig. 45). But the appearance presented by these galls vary considerably, according to the stage of growth at which the potato has been attacked. These swellings may sometimes occur just as the potatoes are forming, and when growth has advanced, the blisters or galls have burst and form rough patches, which may run together and over considerable portions of the potato. Or the tubers may have reached nearly their full size, and then these broken blisters are so numerous and so confluent that the greater portion of the surface is one continuous irregular mass of scab-like excrescences. The appearance of "scab" is even more pronounced when the patches are more or less isolated, and roughened, raised, rounded, or irregular.

There are stages, too, in the potato when no eel-worms are to be seen, and although the surface may give no indications, when the tubers are cut across or lengthwise, there are innumerable little pockets of eggs beneath the skin, just waiting for favourable conditions when the tubers are planted to develop. Such sections are shown in Fig. 55, and some idea may be gained of their numbers when a full-sized potato is seen to have these egg-pockets crowded together beneath the entire surface of the skin.

An expert has been appointed by the Department of Agriculture to investigate the diseases caused by eel-worms, and no doubt he will throw light upon the different effects produced on the potato at different stages of its growth, from a study of the habits of the eel-worm itself. It is, therefore, no part of the duty of this branch to deal with that phase of the subject; but as "scab" was known to be caused by fungi, and since it was supposed that the prevailing forms were due to them, I was induced to investigate the matter from the point of view of finding a remedy before this appointment was made.

### TREATMENT FOR "SCAB."

Experiments were carried out at Bunyip in season 1907-8, with the white-skinned variety Carman No. 1. "Scabby" potatoes, the same as shown in Fig. 51 were used for "seed" and planted in clean land, in plots consisting of 1/100ths of an acre. The "scabby seed" was treated respectively with a solution of corrosive sublimate or mercuric chloride, and formalin, and it was also sown with dry bluestone powder. Corrosive sublimate was used at the rate of 1 oz. in 6 gallons of water, and Schering's or Cuming-Smith's formalin at the rate of 1 lb. in 30 gallons of water. The corrosive sublimate was first dissolved in a few quarts of hot water and then made up to the proper strength, using a cask or wooden vessel, as the solution corrodes metal.



The seed potatoes placed in a loose bag were steeped in the solution for two hours, then cut and planted after being allowed to dry. In addition to the "scabby seed," clean "seed" was taken and artificially infected with scab by shaking up and rubbing the two sorts together.

The following were the results :—

TABLE VI.—RESULTS OF TREATMENT OF SCABBY "SEED."

Plot.	Treatment.	Clean Potatoes.		Scabbed.	Total Yield.		Percentage Scabbed.
		Lbs.	Rate per Acre.		Lbs.	Rate per Acre.	
1	Scabby seed, untreated ..	58	Tons. 2·11	77	135	Tons. 6·0	57
2	Scabby seed dipped in corrosive sublimate solution	195	8·14	2	197	8·16	1
3	Clean smooth seed artificially infected with scab	89	3·19	84	173	7·14	48
4	Scabby seed dipped in formalin solution	194	8·13	30	224	10·0	13
5	Scabby seed sown with dry bluestone powder	81	3·12	70	151	6·15	46

The "scabby seed" planted without treatment yielded 75 per cent. diseased, and even when smooth, clean "seed" was artificially infected there was 48 per cent. of scab, while the "scabby seed" treated with corrosive sublimate was practically clean, only 1 per cent. being affected very slightly. The results were not quite so good with formalin, as 13 per cent. were diseased.

"Scabby seed" planted in a clean soil produced the same, and there is no doubt about the efficacy of the treatment for "scab" when the treated potatoes are planted in land free from "scab." But the question naturally arose what would happen if the treated "scabby seed" were planted in ground subject to eel-worm; and it was to answer this question that the following experimental plots were planted. It was my intention to duplicate the experiments in clean and "scabby" ground, but no clean ground was available. The plot chosen was fully a quarter of an acre, in a long strip, so that each experimental row shared equally the variations in the character of the soil. It consisted of grass land in 1907 when it was broken up, and when planted with potatoes in 1908, the crop was very bad with blister and "scab." In 1909, it was again planted with potatoes, and was practically free from blister and "scab," having only odd potatoes affected.

After the crop was harvested in 1910, a crop of oats was sown and ploughed in when about three feet high. The ground was in excellent condition at the planting season, and about a month before had been manured at the rate of 3 cwt. per acre of bone dust and superphosphate sown broadcast and harrowed in.

For the purposes of the experiment Carman No. 1 was selected, and "scabby seed" of the same variety grown on the farm was used. The same variety was planted and experimented with in 1907, so that the results were quite comparable, the one being planted in clean ground, and the other in ground that had produced scab.

The planting was carried out, and the "seed" cut exactly the same as in the general crop, on 23rd September, 1910.

The crop was inspected on 19th December, and the various rows were all well forward and looking very healthy, as shown in the photograph. (Plate XLIV.)

There were ten separate rows, and the digging took place on 13th February, with the following results :—

TABLE VII.—COMPARATIVE RESULTS OF TREATMENT OF CLEAN AND “SCABBY” SEED PLANTED IN “SCABBY” SOIL.

Plot.	Nature of Seed.	Treatment.	Total Yield.	Smalls.	Scabby.	Per Cent. Scab.
			lbs.	lbs.	lbs.	
1	Clean ..	Steeped in lime-water Bordeaux for $\frac{1}{4}$ -hour	307	41	23	7.5
2	Scabby ..	” ” ” ” ” ”	332	36	91	27.4
3	Clean ..	Steeped in formalin (1 in 40) for 2 hours	263	47	10	3.8
4	Scabby ..	” ” ” ” ” ”	372	40	45	12.1
5	Clean ..	Check—no treatment ” ” ” ”	315	36	13	4.1
6	Scabby ..	Check ” ” ” ” ” ”	264	21	140	53.0
7	Scabby ..	Steeped in corrosive sublimate (1 in 1,000) for 2 hours	363	31	22	6.1
8	Clean ..	” ” ” ” ” ”	324	45	11	3.4
9	Scabby ..	Steeped in bluestone solution (2 per cent.) for $\frac{1}{4}$ -hour	297	36	38	12.8
10	Clean ..	” ” ” ” ” ”	244	32	17	7.0

These experiments with “scabby” potatoes, in which the scab was due to eel-worm, and the “seed” planted in soil subject to the disease, show—

1. That “scabby seed” invariably produces scab in the crop, in some cases amounting to 53 per cent. when the “seed” is untreated.
2. That clean “seed” is always liable to become infected.
3. That treatment of clean “seed” does not protect it from infection.
4. That treatment of “scabby seed” reduces the amount of scab considerably. While the untreated scabby seed produced 53 per cent. of scab, when treated with corrosive sublimate or formalin, it never rose above 12 per cent.
5. That corrosive sublimate is the most effective protection against scab. (Plate XLV.)
6. That the yield from “scabby seed” was invariably increased when treated.

Experiments were also carried out at Burnley Horticultural Gardens with clean and “scabby” Carmans, the same as that used in the experiments at Bunyip. There were twelve short rows altogether with twenty sets planted in each, and a distinction was made between the “seed” in which the blisters were unbroken and that in which they were broken, forming the so-called scab. The ground had been under wheat the previous year, and the planting took place on 4th October, or eleven days after that of Bunyip.

The potatoes were dug on 24th January, when the tops had naturally withered, with the following result:—

TABLE VIII.—COMPARATIVE RESULTS OF TREATMENT OF CLEAN AND "SCABBY SEED" PLANTED IN CLEAN GROUND.

lot.	Nature of Seed.	Treatment.	Number of Plants.	Total Yield.	Scabby.	Remarks.
1	Clean ..	Check .. ..	20	lbs. 19	2 medium-sized potatoes	
2	Scabby ..	.. ..	18	20	6 lbs. ..	30 per cent. Rhizoctonia present
3	Blistered	.. ..	19	26	4½ lbs. ..	17·3 per cent. Rhizoctonia present
4	Scabby ..	Formalin ..	15	13	3 lbs. ..	23 per cent
5	Blistered	.. ..	20	26	4 medium-sized potatoes	
6	Scabby ..	Corrosive sublimate	20	29	1 small potato	
7	Blistered	.. ..	20	25½	2 medium-sized potatoes	
8	Clean ..	Bluestone ..	17	10½	None ..	Whole potatoes used as "sets"
9	Blistered	.. ..	19	16	..	
10	Scabby ..	.. ..	19	23	3 " potatoes	
11	Scabby ..	Lime-water Bordeaux	20	31	5½ lbs. ..	17·7 per cent.
12	Blistered	.. ..	20	25½	4 potatoes	

The yields were variable, and some portions of the ground were very wet during the growing season, so that in such a small area it would be misleading to draw conclusions as to the effect of the different treatments on the relative yield. But as regards the scab, while bluestone was effective, the corrosive sublimate treatment was most satisfactory on the whole. None of the bluestone "seed" produced a blistered crop, but where diseased it was of the nature of scab or broken blister.

If the results are compared when "scabby" potatoes are planted in clean ground, as at Burnley, and on land subject to scab, as at Bunyip, it is found, in a general way, that the clean ground yields practically a clean crop, when the "seed" is free from scab to begin with, and when "scabby seed" is used, under the same conditions, there may be from 30 per cent. or more of "scab" produced. But if the ground is subject to scab, then even clean "seed" will yield a scabby crop, although it may not be very bad, and the "scabby seed" may produce a crop intensely "scabby." When steepes are used, such as corrosive sublimate or formalin, then in clean ground there does not seem to be any advantage when clean "seed" is used, but when "scabby" the corrosive sublimate renders the produce practically free.

## 2. BLACK SPECK, OR SCLEROTIAL SCAB.

This "Black Speck Scab," as it is sometimes called by growers, is very common on potatoes, although it is generally regarded as of little or no importance, because in one stage of its existence it can easily be scraped off, and the skin beneath it is found to be intact. This is only the resting stage of a fungus, however, which is the cause of a potato-rot, and has already been

treated at length under that heading, but it is mentioned here because it may also give rise to one of the numerous forms to which the term "scab" is applied.

It is well known in other potato-growing countries, particularly Ireland, where it seems to be very prevalent, judging by the following statement:—"Perhaps the commonest form of potato-scab in Ireland, and the cause of a potato-rot, too, is that due to the fungus *Rhizoctonia solani*, characterized by the presence of sclerotia [the black specks] on the tuber, and sometimes on the haulm."

In Germany, it would appear that this disease is not considered to be very injurious, since it is not supposed to affect the underlying skin, but that view is founded on a misconception.

The resting-stage, or sclerotium, is confined to the surface of the potato, since it is formed by the converging strands of fungus filaments overspreading the surface like a delicate spider's web. These come together at various points, and roll themselves up into hard masses, which become black. They are in this condition able to withstand the variations of the weather and other injurious influences, and remain attached to the potato until it is again planted and sends out fresh shoots. But there is another stage of the fungus, in which black masses arise at the surface, not from superficial strands, but from deep-seated fungus filaments, or spawn (as shown in Fig. 37). These black "scabs" not only disfigure the surface, but their roots, embedded in the "flesh" of the potato, may, under suitable conditions, produce a brown rot (Fig. 37).

The black scab-like patches stand out clearly when wetted, and the most superficial observer cannot fail to notice them as danger-signals.

The most evident means of escaping this disease is to rigidly reject any tubers showing the slightest black speck before planting, and the further precaution of steeping in corrosive sublimate may also be taken.

### 3. RHIZOCTONIA SCAB.

In treating of *Rhizoctonia* rot, it was pointed out that the fungus causing it passed through three different stages in its life, each of which is so unlike the other, that at first sight they seem to be quite distinct organisms. One stage—the sclerotium, or resting-stage—forms what is known as "Black Speck Scab" on the surface of the potato, and, because it looks so harmless, growers have hitherto been in the habit of treating it with something like contempt. But under suitable conditions of soil and climate, of heat and moisture, these insignificant-looking black specks can produce innumerable fungus-filaments, which may either penetrate the potato, and produce a "rot," or spread all over the surface, and give rise to an unsightly brown scabby mass (Plate XLII.). If such a potato as that shown in the Figure is examined, very little of the normal smooth skin is left, and it is seen to be covered by very delicate, brown, spider-web-like threads. Alongside of these clean patches the surface is raised and broken up, and thrown into folds and puckers, so that you can rub your fingers over it, and a scurf comes off like cork dust. If you examine the base of these "scabs" with a microscope, you will find that the delicate filaments have irritated the skin, and, in consequence of this irritation, have produced the corky layers or "scabs" which, although superficial, reduce the marketable value of the potatoes. Not only does this fungus occur on the surface of the tuber, but the small portion of the stalk, or rhizome, adhering to it is practically one mass of the



filaments, and this shows how the fungus may have reached the tubers from the parent-plant. But the "seed" potatoes may even have been clean, and yet the plant may have become infected, for in the soil, which happened to be a peaty loam, there was abundance of the fungus-filaments disseminated through it. No eel-worm nor insects of any kind were found associated with the disease after a thorough examination of the tubers, and the soil as well. There can be no reasonable doubt that the fungus is the cause of the mischief, and clean potatoes, in thoroughly infected soil, have been planted as a test.

Treatment will be the same as that recommended for *Rhizoctonia* rot, but steeping the "seed" potatoes in corrosive sublimate might be tried to test how far it would be effective in reducing the "scab."

## II. "SCAB" IN OTHER COUNTRIES.

There are numerous varieties of so-called "scab" found in other countries, which, fortunately, have not yet reached Australia, because the organisms causing them have not been introduced, but there are others common wherever potatoes are grown.

A short account of the principal forms due to fungi is here given, with illustrations, to show how varied is their origin, and at the same time to point out their characteristics.

### 1. *American or Oospora Scab* (*Oospora scabies*, Thaxt.).

This is the form commonly met with in America, and is due to a minute parasitic fungus. It may appear on the young tuber, or sometimes, when it has reached a considerable size, in the form of minute reddish or brownish spots. The discolouration usually begins at the lenticels, whence it may spread quite rapidly to adjoining parts. The colour deepens, and an abnormal development of cork occurs in the affected parts, often covering a considerable area. It forms an irregular scab-like crust on the surface, or more frequently the surface is deeply cracked and furrowed. The appearance, as in most skin-diseases, depends largely on the period of attack. If the tubers are infected when very young, then the injury is most severe, as the young scabs soon split and expand with increasing growth, while, if attacked later, when the skin is tougher, there is more resistance offered to the parasite. The delicate mould on the young scabs was first discovered and named as above by Thaxter, in 1890. This disease is controlled by steeping the seed potatoes either in formalin or corrosive sublimate, but this should be combined with a judicious rotation of crops (Fig. 64). The above description of American "scab" is essentially that given by Thaxter, but the fungus alone is never found producing these effects in Australia. It is singular, to say the least of it, that in the most recent American works on Plant Diseases there is only one potato "scab" mentioned, and it is taken for granted that it is the same "scab" which occurs all over the world. It is beginning to be suspected, however, that the fungus *Oospora scabies*, determined by Thaxter in 1890, is not the universal cause of "scab" it was long supposed to be. Thus Duggan, in his "Fungus Diseases of Plants," says—"It is not positively demonstrated, however, that all of the surface injuries known as "scab" are properly referable to this fungus;" and Stevens and Hall, in their "Diseases of Economic Plants," state—"There is some evidence that there is more than one form of disease which passes under this name in Europe." With us this fungus is not of much economic importance.

2. "Corky," Powdery, or *Spongospora Scab* (*Spongospora subterranea* (Wallr.) Johnson = *Sorosporium scabies* (Ber'k.) F. v. W.)

The "scabby" spots are very conspicuous from the damage they cause to the potato. They are at first raised above the general surface of the tuber, and form patches one-eighth to one-quarter inch in diameter. The raised surface becomes ruptured, and the spore-balls of the fungus are seen inside like so many loose grains. The elevation becomes a depression, as the spore-balls fall away, and sometimes these excavations are an inch deep. The parasitic fungus literally gnaws away the surface of the tuber, which, in some cases, resists the parasite by forming a protecting layer of cork, but usually the powdery snuff-coloured spore-balls are the most prominent feature, hence the name of "Powdery Potato-scab" sometimes given to the disease (Fig. 66). The disease was observed in Norway in 1886, and is now known in Germany and Britain, particularly in the west of Ireland. Planting "scabby" tubers propagates the disease, as well as planting healthy tubers in "scabby" soil.

Since the fungus producing this disease is of the same class as that causing the club root or botch in cabbages, turnips, &c., it has been suggested that lime, which is so beneficial in the latter case, might also serve to prevent the other. But, on experiments being tried, it was found that lime, instead of being injurious to the fungus, was actually favorable to it. Steeping the seed potatoes in formalin, and planting in clean ground, had a beneficial effect.

This fungus has only been found on the potato, and may, therefore, be starved out by an alternation of crops.

3. "Black Scab" or "Wart Disease" (*Synchytrium endobioticum* (Schilb.) Percival = *Chrysophlyctis endobiotica*, Schilb.)

This disease was first noted in 1896 in Hungary, and since then it has been found widely distributed in Europe (including Great Britain and Ireland), and quite recently in Newfoundland. Although comparatively new it is a most destructive disease, and was referred to in the House of Commons by the Vice-President of the Irish Department of Agriculture as "that terrible disease known as Black Scab." It is more of the nature of a "wart" than a "scab," and, from the luxuriant growth on the surface of the tuber, it has sometimes been called the Cauliflower Disease. It is regarded as one of the most serious diseases with which the potato-grower has to contend, since it is stated that no sound tubers have been saved from a crop which has been attacked. Unfortunately, it is not noticed until the crop is being harvested, and it is, therefore, liable to contaminate the ground without being observed. When fully developed the disease is easily detected, but in the early stages the tubers may appear sound although the "eyes" are affected.

The disease is spread by means of diseased tubers introduced from infected areas, and, therefore, only sound potatoes should be planted. Also by animals, such as pigs and poultry, and a common means is by the use of manures from animals, especially pigs, fed on raw "warty" potatoes. Even the implements used in cultivating infected soil may carry it to clean ground. The warts may continue to develop even when the tubers are stored.

As regards treatment, various fungicides have been tried without effect. "Variety tests" have also been made, but it is found that the more generally grown varieties are very susceptible. In the *Journal of the Board of Agriculture* for 1910, it is stated that the disease is checked by "greening." Of six diseased potatoes, allowed to germinate in the light for a few weeks, and then planted, only one was affected, while, of six not previously germinated, five were diseased.

Dr. J. H. Wilson, of St. Andrews University, records this disease for Scotland as early as 1901, when it was also first reported in England. A Federal proclamation has been issued, prohibiting its importation into Australia, and the common names applied to it are potato canker, black scab, warty disease, and cauliflower disease (Figs. 67, 68).

4. *Scurf* or "Dry Scab" (*Spondylocidium atro-virens*, Harz = *Phellomyces sclerotiphorus*, Frank).

This "scab," or scurf, appears in the form of larger or smaller patches of various colours, either whitish or light-brown. When these patches are numerous or confluent, the scabbing becomes very prominent. On these discoloured patches dot-like sclerotia occur, forming minute black specks, just visible to the naked eye. The sclerotium may appear on the same potato with that of *Rhizoctonia*, but the one is easily distinguished from the other. In *Rhizoctonia* the sclerotia are much larger, more conspicuous and projecting, and the cells are at least twice the diameter.

The fungus insinuates itself between the different layers of the skin of the potato, causing them to peel off like tissue-paper, and this exposes the tissue beneath. Under these conditions, dry rot may follow the "scab."

The disease may either be introduced by means of infested tubers, or the fungus filaments may pass from the soil on to healthy tubers (Fig. 69).

The foregoing account of the varied forms of skin disease emphasizes the necessity for determining the nature and mode of working of the agent responsible for the effects, before any measures for prevention can be devised with a reasonable hope of success.

(Plates XIV., XV., XVI., XVII., XVIII., XX., XXI., XXII., XLIII., XLIV., XLV.).

## V.—DRY ROT AND "BROWN RING."

(*Fusarium oxysporum*, Schlecht. = *Fusarium solani*, Sacc.).

The disease to which this name is applied varies in its symptoms at different stages, so that it has been variously named by growers. There was a serious disease of the potato brought under my notice some years ago, called the "Brown Ring," and it caused considerable loss in seasons when it was prevalent. The smooth-skinned variety Beauty of Hebron was particularly subject to it. The brown ring was so called because on cutting across stored potatoes particularly, the area occupied by the vessels was found to be discoloured, being brownish or blackish (Fig. 89). When the tissue from this brown ring is examined under the microscope, the walls of the vessels are seen to be the portions discoloured, and when a slice from such a diseased potato is placed under a bell-jar, and kept moist, abundance of white fungus filaments are developed, which in cultures produce a *Fusarium* (Fig. 148). The surface of some of the potatoes that had been stored was also covered with a white mould belonging to the same fungus, and bearing abundance of conidia (Fig. 72).

Hence the disease is sometimes also called the "White Rot," and the generally-used term of "Dry Rot" indicates that the tubers become shrivelled and transformed into a dry, somewhat hard, crumbling mass of a greyish colour, if bacterial decay does not set in.

## FUNGUS CAUSING DISEASE.

The fungus causing this disease has been variously named. It is commonly known as *Fusarium solani*, Sacc., but some consider that the fungus earlier named by Schlechtendal *Fusarium oxysporum* is the same. I have adopted this name because the reproductive bodies or conidia produced in some cases are very acute at both ends, as in this species.

The disease has also been attributed to *Nectria solani*, Reinke and Bert-hold, considered to be the complete stage of the above fungus, but no such fungus has been found associated with it in Australia, even although diseased specimens have been kept for some time under observation.

## NATURE OF FUNGUS.

The fungus usually enters the plant through the roots, thence into the underground stems bearing the tubers, and through them into the tubers themselves. The mycelium or spawn is colorless, and composed of comparatively slender filaments, with numerous partitions, and much branched, as it ramifies among the cells. When it appears at the surface, in the form of tufts, it may either be snow-white or of a pinkish tint, and bears innumerable conidia. These conidia are borne at the end of the numerous branches, and are usually slightly curved, with three to five septa or partitions, the average number being three. (Fig. 74.) The conidia are pinched off at the ends of short branches, and as they fall away when ripe, others are formed in their place (Fig. 73). It is difficult to say how many may be formed in this way, but as many as five have been counted produced by the same branch, so that the supply of conidia must be practically unlimited during the growing season. But this is only one of several modes of reproduction, as shown when the germination of one of these conidia is allowed.



## GERMINATION OF CONIDIA.

The conidia germinate very readily in moisture, but they only retain their germinating power for a limited period, how long has not been actually determined. Conidia taken from potatoes placed in store in July, 1909, failed to germinate when tested on 30th March, 1910, even after being kept under favorable conditions for seven days, so that eight months after they had lost their vitality.

A number of germinating tests were made with fresh conidia, to see the time required for successful germination. When placed on a slide in tap water, germination took place in three hours, and filaments were produced from one, two, or three cells of the conidia. In some instances there was luxuriant germination in sixteen and twenty-four hours, and sometimes, with conidia from the same potato, there was only slight germination at the end of eighteen hours, the result probably depending on the different temperature of the laboratory on the date at which the test was made, as well as the age of the spore. All the experiments were carried out between 1st and 14th April. As a final test, six slides with conidia were placed, under similar conditions of moisture at the same time, and in twenty-four hours there was luxuriant germination in all of them, only about 1 per cent. failing to germinate. Germination takes place either at one end of the conidia, or at both ends, or laterally. About 80 per cent. germinated only at one end, 10 per cent. at both ends, and the remainder laterally as well, but none germinated from the median cells alone. (Plate XXIV.).

The effect of formalin on germination was also tried. Conidia were placed in a solution of formalin (1 in 40) for five minutes, and then rinsed with clean water. Thousands of conidia were thus treated, but, after several trials, no germination took place, even at the end of seven days.

The ordinary mode of germination consists in the production of long, slender, septate filaments, which usually give rise to longer or shorter branches, without any further development outside of the potato-plant, but in some cases a short secondary conidium was produced at the end of a branch at a short distance from the primary one. (Fig. 79.)

## CONIDIA IN CLUSTERS.

The aerial conidia are formed in the manner described, under normal conditions, but when the conidia are placed under relatively dry conditions, with just sufficient moisture to enable them to germinate, then they behave differently.

On a potato which had been inoculated and kept dry under a jar for seven weeks, there was a dense, white *Fusarium* mould. Conidia taken from the surface of the mould were found to be germinating and producing filaments bearing conidia in turn. The conidia, however, were not produced solitary or in chains at the ends of branches, as in the ordinary form, but in clusters, and the filament continued its growth and produced another cluster, and so on. When seen in dry air, these filaments looked like knotted cords, and whenever water touched the conidia they fell away. These knots were oval in shape, and consisted of numerous conidia (sometimes as many as thirty were observed) arranged longitudinally around a central conidium produced at the end of the filament. The conidia in the same cluster were at different stages of growth, some being without and others with septa, the youngest being invariably in the centre. They were straight or slightly curved, septate or non-septate, just as in the ordinary form, only they were not so fully matured (Fig. 81).

Sometimes the tufts of conidia, instead of being borne in succession along the length of the filaments, were produced at the tips of short lateral branches, which were given off in regular order along one side.

The same kind of germination was produced artificially when conidia were placed on damp blotting-paper, sufficient moisture being present to keep them from drying up. The conidia were taken from the same potato, not from the surface where there was a white efflorescence, consisting of conidia germinating as above, but from a pale yellowish moist substratum beneath that and next the skin, in which the conidia were still germinable. The amount of conidia produced in this way at the surface of the mould must be enormous.

#### RESTING SPORES, OR CHLAMYDOSPORES.

The fungus is thus able to adapt itself either to moist or dry air, and reproduce itself luxuriantly under these conditions. But even when submerged, or kept very moist, the conidia are still capable of germination, and produce reproductive bodies, which are able to persist, until more favorable conditions arise. These bodies are commonly called resting spores, or chlamydospores, because they are thick-walled, and are more resistant to unfavorable conditions than the ordinary conidia. (Plate XXV.)

On a potato infested with the fungus, and which had been kept under moist conditions for fully two months, the resting-spores were found in great abundance. It had become quite soft and slushy, and large patches of a dirty-white or wash-leather colour appeared. These indicated the resting-spores, as shown in Fig. 86. They are seen in all the different stages of development, as solitary at the end of a filament, or several in succession forming a chain, or even as a swelling in the course of a filament.

When the ordinary conidia were placed under water, they began to germinate in the course of three hours. They either put forth a slender germ-tube as usual, or this might be entirely suppressed; but the peculiarity consisted in the formation of reproductive bodies different from the conidia producing them within six to seven days. Resting-spores usually arise as swellings of the hyphae, either on long, generally straight, filaments, or on short lateral branches. There may be several together like a string of beads, or they may arise at the end, when they are terminal, and may either be solitary or form a chain. They may even arise direct from the conidium without the intervention of a germ-tube, either laterally or terminally. (Figs 82, 83, 84.)

The Figures show the wonderful variety in the mode of formation of these resting-spores. They may be produced direct at one end of a conidium, and a germ-tube at the other, or a germ-tube may be formed at either end, and the resting-spore laterally, or even the germ-tube may sometimes produce a lateral as well as a terminal spore.

The mature resting-spore is a spherical or ellipsoid body of a yellowish-brown colour, with a wall sometimes three micro-millimetres ( $\mu$ ) in thickness, warty, irregular, or smooth. It varies in size from 8–13  $\mu$  when attached, and when fully mature and detached, 16–22  $\mu$ . (Fig. 85.)

#### INFECTION OF POTATO BY POTATO.

There has been some doubt expressed as to whether this fungus actually causes the disease, and Masee, even in his "Text-book of Plant Diseases" (1909), dismisses the subject with the remark, "*Fusarium solani* Sacc. is said to cause the rotting of potato tubers, but the matter requires further investigation." Experiments have been carried out by various investigators showing that healthy potatoes may be infected from diseased ones, and the matter has also been investigated by myself.

The healthy potatoes used in this experiment belonged to the variety known as Carman No. 1. That they were absolutely free from this disease was clearly shown in the first experiment, in which one of the potatoes was deeply cut with a sterilized knife in various places, and the end cut off, so as to expose a large cut surface. The specimen was kept moist under a bell-jar, and at the end of 24 days it was found to be perfectly clean. (Exp. 1.) In the next experiment one of these healthy potatoes was infected from a diseased one. Pure conidia were placed on the unbroken skin at the base of the "eyes," and in seven days *Fusarium* appeared on the young shoots, causing their tips to become brown and withered. So that a young potato shoot could be infected in this way, causing it to die off, but the tuber itself was not then apparently affected. (Exp. 2.) When, however, a healthy potato was infected where the skin was broken, an abundant growth of the *Fusarium* was obtained in seven days, together with symptoms of "dry rot" in the tuber. (Exp. 3.) Even when the skin was unbroken infection might occur. Very young healthy potatoes, about the size of peas, were inoculated on the unbroken skin, and in four days the *Fusarium* appeared. The fungus not only caused a browning of the skin at the spot where infected, but had penetrated beneath the skin and caused a slight browning of the tissue. (Exp. 4.)

It is evident, therefore, that healthy potatoes can be infected from diseased ones, especially when the healthy potato is wounded either in digging or otherwise, and very young potatoes with a tender skin can be infected even although the skin is unbroken.

#### INFECTION OF POTATO BY TOMATO.

A clean potato, with unbroken skin, was infected with conidia from the tomato on a portion of the surface away from the "eyes," but it was still clean after 24 days. (Exp. 5.) When a clean potato, however, with broken skin was infected from the tomato, infection took place in six days, and the conidia of the fungus appeared. (Exp. 6.)

The potato can, therefore, be infected by the conidia of *Fusarium*, whether they arise from the potato or tomato, and the next step is to see if the tomato can be similarly infected.

#### INFECTION OF TOMATO BY TOMATO.

A clean tomato, with broken skin, was kept as a check, and at the end of 24 days it was still clean. (Exp. 7.)

A clean tomato, with unbroken skin, was infected, and in fourteen days the conidia of the fungus appeared on the surface. A small sunken circular spot appeared at the end of ten days, and in 24 days one end of the tomato was covered with a pure white crop of *Fusarium*, and a softening took place all around it. (Exp. 8.)

Infection took place much more quickly when the tomato was wounded. When the tomato was inoculated on a wound the *Fusarium* appeared in six days, and at the end of 24 days the tomato was soft and decayed with a crop of mould covering the top. (Exp. 9.)

#### INFECTION OF TOMATO BY POTATO.

A healthy tomato was infected on the unbroken skin, and the fungus was produced within 24 hours. Up to five days the *Fusarium* alone appeared on the surface, but after that other fungi appeared as scavengers and completed the decay of the tomato. (Exp. 10.)

Finally, a healthy tomato with the skin broken was infected at the wound, and within 24 hours the *Fusarium* appeared, as shown in Fig. 90. (Exp. 11.)

TABLE IX.—MUTUAL INFECTION OF CONIDIA FROM POTATO AND TOMATO.

The preceding experiments show that the conidia of *Fusarium* on potatoes and tomatoes are mutually infective, just as the *Phytophthora infestans* can also pass from one to the other.

The following table summarizes the results obtained when specimens were kept moist under a bell-jar :—

No.	Experiment,	Source of Infection.	Result.
1	Healthy potato, with broken skin .. ..	..	Still clean after 24 days
2	Healthy potato, infected on unbroken skin at eyes	Potato	Young shoots only affected and producing mould in 7 days
3	Healthy potato, with broken skin, infected at wound	"	Fungus produced at wound in 7 days
4	Very young potato, with unbroken skin, infected	"	Fungus appeared in 4 days
5	Healthy potato, with unbroken skin, infected away from "eyes"	Tomato	Still clean after 24 days
6	Healthy potato, with broken skin, infected at wound	"	Fungus appeared in 6 days
7	Healthy tomato, with broken skin .. ..	..	Still clean after 24 days
8	Healthy tomato, with unbroken skin, infected	Tomato	Fungus appeared in 14 days
9	Healthy tomato, with broken skin, infected at wound	"	Fungus appeared in 6 days
10	Healthy tomato, with unbroken skin, infected	Potato	Fungus appeared in 24 hours and tomato ultimately destroyed
11	Healthy tomato, with broken skin, infected at wound	"	Fungus appeared within 24 hours

It will be observed that the tomato, whether with broken or unbroken skin, was readily infected with conidia from the potato; but when conidia from the tomato itself were used, infection was much slower. The potato, on the other hand, with broken skin was not infected for six or seven days, whether conidia from potato or tomato were employed, and with unbroken skin infection did not occur, unless in the case of very young potatoes with tender skin, or when applied to the "eyes" of mature tubers. Massee has noted the appearance of this fungus on the tomato plant, causing the non-development of the flowers and the withering of the inflorescence.

Recent experiments were also carried out by Pethybridge and Bowers, which proved conclusively that healthy tubers may contract the disease by contact with the diseased ones, and, to establish the parasitic nature of this fungus beyond dispute, pure cultures were used. The results may be given in their own words :—"The certainty and ease with which these wound-inoculations with pure cultures succeeded, made it unnecessary to carry the matter further, and it is quite clear that *Fusarium solani* is a true parasite capable of directly producing the disease known as 'dry rot' in absolutely healthy potato tubers. The tubers developed the disease in a perfectly typical manner, and eventually became totally shrivelled up to a dry hard mass."

From the study of the diseased potato plant itself, as well as of the tuber, there are seen to be various modes of infection. The fungus enters the plant beneath the surface of the soil, through the roots to begin with, whence it can easily spread to the base of the stem, then to the underground branches, and finally to the tubers at the end of them. The fungus must therefore be in the soil in some form, probably as resting-spores, and the germ-tubes from them will penetrate the delicate rootlets, and ultimately reach the tubers.



This roundabout way of reaching the tuber is not always necessarily followed, for the shoots of the seed potato may be directly infected from the germ tubes of the conidia planted with it, and the filaments of the fungus would directly pass through the underground portions of the stem into the tubers. But there is even a more direct way of infecting the tubers, for the fungus may enter through wounds, or even through the unbroken skin when young and tender.

Dry rot is generally regarded as a disease of the tubers only, but it may also attack the "collar" of the stem and cause rotting there.

#### LIFE HISTORY OF THE FUNGUS.

The life history of this fungus, as occurring in Australia, may be briefly summed up as follows:—

1. *Fusarium stage*.—Under normal conditions of heat and moisture the mycelium or spawn of the fungus inside the tuber produces its fructification on the surface of the skin in the form of snow-white tufts, bearing innumerable curved and jointed conidia. When these are placed on a healthy potato, where the skin is broken, or even on the unbroken skin of young potatoes, they germinate and enter the tuber, again producing the *Fusarium* stage at the surface in the course of four days. (Figs. 72, 73.)
2. *Cephalosporium, or Cluster stage*.—On a potato, which had been inoculated with the *Fusarium* conidia and kept for seven weeks, the dense white mould which appeared on the surface produced conidia somewhat differently from the preceding. Instead of being solitary or in chains, they were in round or oval clusters, either at the tips of short lateral branches or in succession along the same filament. The individual conidia were curved and jointed as in the *Fusarium* stage. Conidia were taken from the same potato and germinated artificially on damp blotting-paper, just sufficient moisture being present to prevent them drying up. They produced the clustered conidia as above, and thus the mycelium is capable of forming either solitary or clustered conidia, according as the air is moist or relatively dry. (Fig. 81.)
3. *Chlamydospore, or Resting-spore stage*.—But even when completely submerged or kept very moist, this fungus is still capable of reproducing itself. Under these conditions it forms rough, brown, thick-walled spores, known as Resting-spores, because they are able to tide the fungus over unfavorable conditions. They are either produced in succession along a filament like a string of beads, or they may be formed at the end of a branch either solitary or in chains. They have been produced directly at the end of a conidium, so that there is no doubt as to their origin, but I have not yet followed out their germination. (Figs. 85, 86.)

#### PREVENTIVE MEASURES.

Although we do not know the complete life-history of this fungus, there is sufficient information to guide us in making recommendations. How long the fungus keeps alive in the soil has not been determined, and how long the spores retain their vitality is not known, but it has been proved that healthy tubers can contract the disease from the soil.

1. There is a counsel of perfection which can be given with safety in this as well as other potato diseases, and that is to plant only sound tubers obtained from localities where the disease does not occur, and plant in soil free from the fungus.

2. It would be difficult to carry out the above in practice, but in order to avoid the infection of healthy land by diseased tubers the stem end of every tuber intended for seed should be cut and inspected before planting, and any showing "brown ring" should be rejected and destroyed. Cut seed would thus have the advantage over whole seed, as it would show any discoloration inside the potato.
3. Infected land should not be planted with potatoes for a series of years.
4. Diseased tubers should not be thrown on the manure heap.
5. Tubers should be stored in a dry, cool, well-ventilated place, since heat, moisture, and the exclusion of air are conditions favorable for the development of this disease.
6. It is well known that this disease often develops in store; therefore any suspicious-looking tubers should be rejected when digging, and not stored.
7. Stored potatoes should be frequently turned over, so as to detect any appearance of the disease, and remove such affected tubers at once. Massee recommends the sprinkling of powdered sulphur over the potatoes at the rate of about 2 lbs. to the ton in order to check the development of the fungus.
8. As wounded surfaces are very liable to infection, care should be taken when digging, and afterwards handling, to avoid wounding the tubers.
9. From the risk attendant on wounded tubers, they should not be used as seed.
10. Since steeping the conidia for five minutes in formalin solution (1 in 40) prevents their germination, treatment of the seed potatoes in a similar way would destroy the germinating power of any adhering to the surface of the tuber.
11. Some varieties, such as Snowdrop, are very susceptible to the disease, and a selection from resistant plants of other varieties might be made.

(Plates XXIII., XXIV., XXV., XXVI., L.).

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## VI.—WET ROT, BROWN ROT, SORE EYES, OR BACTERIOSIS.

( *Bacillus solanacearum* E. F. Smith.)

This is a type of a class of diseases which are very destructive in their effects, and which are only beginning to be studied, so that the number is being added to year by year. They are caused by microbes or bacteria, and numerous instances are known where these organisms simply act as scavengers, and only appear after disease has been set up by some other means. The great majority are of this nature, and it has even been called in question whether they ever originate disease; but there are several well-known cases in which they are proved by infection experiments to produce the disease, and this is one of them. The great secret of their success as plant-destroyers lies in their immense powers of multiplication, and it has been reckoned that a single tobacco plant affected with the same disease as the potato may contain ten thousand million of these bacteria. The disease has been known for a number of years in Australia, and is familiar to growers from the offensive odour associated with it, as well as the slushy "rot" which sometimes entirely fills the skin of the potato, so that on bursting nothing but a putrid mass oozes out. It spews out like rotten, clotted cream.

It also occurs in Britain, and is well-known in America, where it has been thoroughly investigated from the bacteriological point of view by Dr. Erwin F. Smith.

Although this disease first became generally known through the comprehensive description of it by Dr. Smith, published by the United States Department of Agriculture in December, 1896, in a bulletin entitled "A Bacterial Disease of the Tomato, Egg Plant, and Irish Potato," yet it had previously been discovered and investigated by Mr. Tryon, Government Entomologist and Vegetable Pathologist of Queensland, who made known the true nature and cause of it as early as May, 1894, in a "Preliminary Report on a new Potato Disease prevalent in Southern Queensland." In a further paper in the *Queensland Agricultural Journal*, July, 1899, he showed conclusively that the American and Australian diseases were identical, and that the same bacterium occurred in connexion with both, viz., *Bacillus solanacearum*, the new species determined and named by Smith.

## SYMPTOMS.

The first indication of the disease is the sudden wilting of the foliage, and the shrivelling of the leaves is soon followed by a discoloration of the stem. (Fig. 97.) Dark-brown streaks are seen, and these gradually pass downwards into the underground branches, and so ultimately reach the tubers themselves. It is only when it has reached and affected the tuber that the disease is usually taken notice of by the grower, but it may just as readily be detected in the discolored stems.

When the stem is cut across in the early stages of the disease, the woody cylinder is seen to be brown and discolored, with the slimy, dirty-white bacteria oozing out all round. (Fig. 97.) The tuber may at first appear perfectly sound, but, on making a section of it towards the stem end, there is seen a more or less complete pale-brown ring, situated a little inward from the skin, as in Fig. 97z. Then this broadens and darkens in colour, until the ring may even extend to the skin as well as inward. (Fig. 94.) There is no risk of confounding this with the "brown ring" due to *Fusarium*, for there is the grayish-white bacterial slime oozing out. When some of the potatoes.

from which the photographs were taken, were placed in spirit, the extraction of the water and the consequent shrinking forced the bacteria out through the eyes in large curling masses. (Fig. 95.) The solid masses of bacteria supplied visible evidence of their immense numbers. Even while still underground there is an exudation from the eyes, which on account of its sticky nature causes the earth to adhere at these points, so that when removed from the soil the eyes are all blocked up, and at this stage the grower gives the disease the expressive name of "sore eyes." (Fig. 91.) Ultimately the potatoes become a seething mass of corruption, and, when dug, you can see them with the unbroken or broken skin, and the dirty-white slimy fluid streaming out, polluting the air with an offensive odour.

The indications which may be relied on, are the following :—

- (a) A wilting of the plant.
- (b) A watering of the eyes, associated with a frothy exudation.
- (c) Adhesion of soil to the eyes by means of a sticky substance.
- (d) A brown or black rot commencing at the stem end of the tuber in the vascular ring and extending in all directions.

#### CAUSE.

The disease is caused by a microbe or bacterium which lives and multiplies in the vessels of the plant. (Fig. 98.) These vessels are filled with innumerable bacteria, constituting a sticky, pus-like fluid, and this choking of the vessels prevents air and nutriment being distributed throughout the plant, so that the tops wilt and die while the tubers become diseased. It does not necessarily follow from the mere presence of bacteria in a plant that they are the cause of disease, and, to prove it, it is necessary to inoculate the plant with the germs under proper conditions and produce the disease, while another plant grown under similar conditions, but without being infected, remains healthy. Pure cultures of this organism were used to infect the potato plant, and in fifteen days the wilting occurred as shown, while the healthy uninfected plant remained healthy. (Fig. 97.) How they gain an entrance into the host plant is an important question, and, so far as known, they can only enter through wounds.

#### NATURE OF THE ORGANISM.

The immense powers of multiplication possessed by these organisms, combined with their ability to dissolve the cell-walls of plants and set up putrefactive changes, render them very destructive. Another factor of considerable importance is their power of continuing to live and grow outside of the potato or other host-plants. The soil in this way may become infected, and healthy plants grown in such soil may contract the disease. When isolated from their host-plants, however, these organisms become less virulent, and their power of causing disease may die out altogether; but they are known to retain their vitality in the soil for a period of years, and several cases are recorded where five to eight years' rest of the soil did not prevent a return of the disease. They are also sensitive to heat, and Smith states that if the whole body of the soil could be warmed up to 125 degrees Fahr. for fifteen minutes they would be destroyed.

#### HOST PLANTS AND DISTRIBUTION OF DISEASE.

This disease occurs on various members of the Potato family. It has been determined by Dr. Erwin F. Smith, in the United States of America, on potatoes, tomatoes, and egg plants (*Solanum melongena*), as well as on tobacco plants, and a wilting of the leaves is a characteristic sign of it. In



the State of North Carolina, in 1908, it is estimated to have caused a loss of upwards of £20,000 in the tobacco crop, and it is stated that if it continues at its present rate of progress it will threaten the existence of the tobacco-growing industry. It has also been recently observed in Britain on potatoes, and it has been found in New Zealand, Queensland, and Victoria on the same crop. In all probability it exists in the other States of the Commonwealth. In Victoria it is the cause of considerable loss, and is particularly bad in swampy ground which has been reclaimed.

#### PREVENTIVE MEASURES.

As in the case of potato blight, measures have to be directed towards preventing its introduction into a district, as well as dealing with it when it has already appeared. Since bacteria are so ubiquitous, and possess such immense powers of multiplication, the only safe course is to prevent its access to the soil through the seed potatoes.

The following measures are, therefore, recommended :—

1. In planting fresh ground, seed potatoes should be obtained from a district where the disease is not known to exist.
2. Seed potatoes may be heated as recommended for potato blight, since that heat is fatal to the organism causing the disease.
3. Potatoes should not be planted on infected land, and even after several years it is not safe to do so.
4. No plants belonging to the Potato family should be used as a rotation on infected land, as even weeds of this family are subject to it.
5. Affected plants should be removed and burned as soon as detected. The longer they are left in a field, the greater the danger of increasing the soil infection.
6. All refuse, such as potato tops and decaying tubers, should be removed and destroyed. I have usually seen the "slushy" potatoes left on the field, as the growers do not realize the risks they run.
7. To prevent the infection of clean fields, care should be taken not to carry the earth from an infected field by means of implements, feet of horses and cattle, on one's boots, &c. In fact, one should always cultivate a clean field first, and implements should be disinfected, which may be done by a short exposure to live steam, or by means of corrosive sublimate, obtainable in the form of tabloids.
8. The disease may also be transmitted from plant to plant by leaf-eating or leaf-puncturing insects, and therefore spraying with an insecticide would indirectly check the disease.
9. The wettish spots in a field are generally the worst affected, showing that drainage, while not an absolute remedy, has a beneficial effect.

(Plates XXVII., XXVIII., XXIX.)

## VII.—"BLACK LEG" OR "BLACK STALK-ROT."

(Bacillus sp.)

"Black leg" is the popular name given to this disease, but since it is also applied to a well-known disease in cattle in this country, and to a common disease in cabbage and cauliflower, the suggestion has been made to call it "Black stalk-rot." Although we talk of "scab" in sheep, it does not cause any confusion to apply it to potatoes, and so "Black leg" is such an expressive name for the disease that it is adopted here. This disease affects all parts of the plant, causing the stem and leaves to assume a yellowish-green colour, then to turn brown, and finally the leaves collapse and dry up. The entire plant dies down, and the underground portion of the stem shows the seat of the trouble. This is quite black and decaying, so that it is readily understood how the leaves gradually die from below upwards, and the stalks collapse. The result is that no tubers, or only very small ones, are developed. When affected plants are dug up, the "set" or seed potato is found to be completely rotten.

Signs of the disease may appear as soon as the plants are above ground, or at any intermediate stage up to flowering time. It may be confined to only one stalk of a plant, or all the stalks of the same plant are frequently attacked, especially when the disease has reached its full development. In later stages of the disease the yellowish or pale-green colour of the leaves is, as a rule, very conspicuous. It is usually only plants here and there that are affected, but it may be so commonly distributed that the yield is seriously reduced, sometimes even to the extent of 75 per cent.

## CAUSE OF THE DISEASE.

If the blackened portion of the stem underground, in the early stage of the disease, is examined, the tissues are found to be decayed, and more or less soft and rotten. But if the firm portion above the level of the ground is cut across, the section shows three dark-brown spots. These spots indicate the vascular bundles of the stem, which have become disorganized through the action of organisms. In fact, one finds various organisms associated with the decay; but if this is followed up to the boundary of the sound tissue, there the presence of bacteria is decidedly in evidence. The young tubers may also have black patches, and the vascular ring often shows a black discoloration. The damp, muggy weather, which favours potato blight, causes this disease to spread rapidly, and numerous specimens were sent to me during the past season along with the other.

Dr. Appel has named the specific organism causing this disease in Germany *Bacillus phytophthorus*, and what is probably the same disease in Canada is said by Harrison to be caused by *B. solanisaprus*. Dr. Pethybridge has found a similar disease in Ireland caused by *B. melanogenes*, and the distinct species causing it in Australia will require to be settled by the Plant Bacteriologist, whenever such an officer is appointed.

## DISTRIBUTION.

Although this disease has only been specially noticed this season (1910), occasional specimens have been sent to me in previous years. It is known in Britain, as well as in France and Germany, where it is popularly known as *Schwarzbeinigkeit*, or Black Leg. Also in the United States and Canada, and probably in other States of the Commonwealth besides Victoria.

### EFFECTS.

Although the disease was only observed in the growing crop in isolated plants here and there, and the loss from that source was therefore not serious, yet it may also occur in stored potatoes, where the loss might be considerable. Pethybridge and Murphy have proved experimentally that perfectly sound tubers may become infected by contact with diseased ones; so that, under suitable conditions of heat and moisture, very serious rotting might occur.

In some cases the disease in the tubers may be so slight that they may be planted as "seed" potatoes, but the parasitic bacteria will become active and produce the rotting of the stalks sooner or later.

### PREVENTIVE MEASURES.

Bacterial diseases are, as a rule, difficult to cope with, on account of the immense powers of multiplication possessed by the microbes, and the rapidity with which they are spread. Hence, whatever measures tend to limit their numbers or prevent their spread, should be adopted. The use of formalin or bluestone solution has not been found to be beneficial, since they do not penetrate the skin of the potato and reach the bacteria in the interior.

1. The decaying and rotting parts of the plants are swarming with bacteria, and in order to prevent the soil becoming contaminated with them, they should be removed as soon as they show symptoms of the disease and burned.
2. Healthy seed should be selected by picking the tubers from healthy plants when the crop is being lifted, and placing them in boxes for sprouting at once. Or, better still, the seed potatoes should be obtained from districts free from the disease.
3. The potatoes should be planted in well-drained land, or in land not likely to become water-logged. The diseased specimens photographed were obtained from reclaimed swampy land, and the water could be pressed out from the soil by squeezing it in the hand.
4. There should be a rotation of crops. If potatoes are planted in the same soil year after year, they are liable to increase the chances of infection, and to encourage the multiplication of the bacteria. Cereals are not subject to the disease, but, according to Dr. Appel, who has made a special study of the subject, beans, beet, carrot, cucumbers, mangolds, turnips, and vegetable marrows are all susceptible to it, and should not, therefore, follow potatoes on land where the disease has occurred.
5. Lime and strong nitrogenous manures should be avoided, as they encourage the disease.

Pethybridge, as the result of his studies, has stated that "preventive measures should, therefore, aim at the destruction of diseased plants, the exclusion of affected tubers from the pits, and the procuring of tubers for 'seed' purposes from crops in which the disease has not appeared." He is also testing experimentally if the organism can be killed by heat without injury to the tubers themselves, and since the thermal death-point is not above 50 degrees C. (122 degrees Fahr.), this can be safely done.

(Plates XLVI., XLVII.)

## VIII.—BLACK DOT DISEASE.

*(Vermicularia varians* Duc.)

Towards the end of January potato plants were brought under my notice which had grown luxuriantly, but afterwards the stems became dry and the green leaves shrivelled up. Ultimately the stem became continuously and densely covered with minute black bodies, either separate or confluent, and these black points constitute the essential characteristics of the disease. The black dots extended to the tips of the underground portions, but they were not conspicuous on the tubers or leaves.

In May a potato plant belonging to the White Elephant variety was brought under my notice, which had been grown in a specially prepared soil, reaching a height of 11 feet, and bearing several large tubers. This disease was found upon the stems, and since the seed potatoes were brought out from England a few years ago, it was probably in this way that the disease reached Australia. The same plant was also affected with Irish Blight, both in tops and tubers, and probably both diseases were introduced together. A disease of potatoes and tomatoes was described in France in 1909 caused by the same fungus, but it has not been recorded on the tomatoes here. It was not observed at first on the tubers; in fact, the potatoes were well-grown and apparently sound, and it was this discrepancy between the healthy tubers and diseased tops which attracted the attention of one of our inspectors.

## SYMPTOMS.

This disease appears on the stems while still quite green (Fig. 141), and it is the lower portions of the plant which are first attacked. It descends to the roots and creeps up the stem, until finally they blacken and become quite brittle. Ultimately the stalks are quite black and dead, and the leaves are all brown and shrivelled up. (Figs. 137, 138, 139.)

The black dots not only occur on the root and stem, but, when the withered leaves are carefully examined, they are also found on the leaf-stalks as well as on the leaflets.

There is usually a fair crop of potatoes, which are fully formed and apparently healthy. When carefully examined, especially towards the stem end, the skin is dotted all over with minute black dots (Fig. 140), which, on microscopic examination, show the characteristic features. These dots occur on the tubers at all stages of growth, on the young as well as on the fully formed, and they can be seen passing from the stalk to the skin of the potato. Hence they are most numerous at the stalk end, and towards the crown end they may be absent or only a few scattered ones.

The course of the fungus can be readily followed. It covers the stems even to the extreme tips, then passes along the underground branches to the tubers, and extends from the stalk over the potato. The sclerotia are also developed inside the hollow stem, but they never reach above ground, and extend along the inside of the underground branches to the tubers.

## FUNGUS CAUSING DISEASE.

The fungus causing this disease assumes various phases, and the black, dot-like form is only one stage of its life history. It first appears as minute white tufts on the surface of the stem, consisting of short, colourless filaments, bearing colourless conidia or reproductive bodies at the top. From the base of these tufts a number of black rigid hairs grow out, which are slightly swollen at the base, and tapering towards the apex. Then underneath the skin, and often below the preceding stage, black sclerotia-like bodies are produced, which ultimately burst through and form the black dots studding the surface.



When sections of these black bodies are examined, they are seen, as in Fig. 142, to be solid sclerotia, with numerous black rigid hairs on top, among which innumerable colourless conidia are being produced, similar to the first forms.

This is the most advanced stage as yet met with in Victoria, but in France the sclerotia have been found developing into mouthless pycnidia, or spore cases, with spores in their interior.

While the sclerotia are generally superficial, they become embedded in the tissue of the stalks producing the tubers. The sclerotia produce the colourless conidia under ground as well as above ground, but, as far as I observed, they were not produced there in such profusion. On the dead stems whitish patches often occur, studded with numerous black, superficial flattened pycnidia, without bristles and opening by one or two pores. The contained spores are continuous and colourless, and the fungus is a *Phoma*, which is probably saprophytic. (Fig. 139.) The tubers were also sometimes affected with "wet rot," even although the black sclerotia were evident upon the surface of the skin.

#### EFFECTS PRODUCED.

The blackening of the stems and the browning and shrivelling of the leaves are very evident, and if this takes place before the tubers are matured, it is bound to reduce the yield. But the tubers themselves appear quite firm and healthy, even although there may be numerous black dots upon the skin. If infected tubers, however, are used as seed, the mycelium or spawn may pass into the young tubers and destroy them. The young tubers may also become infected, through sclerotia being in the soil from a previous crop.

#### PREVENTIVE MEASURES.

From the nature of the disease, all the haulms should be collected and destroyed by burning, since the sclerotia in the soil would perpetuate the disease.

Tubers grown from such plants should not be used as "seed," even although apparently healthy, for the sclerotia are so minute that they could easily be overlooked, especially if few and scattered. A rotation of crops should be practised, since we do not know how long the sclerotia may remain in the soil and retain their vitality.

(Plates XLVIII., XLIX.)

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## IX.—SCLEROTIUM DISEASE.

This disease has been observed occasionally in potatoes, but not to any great extent. In tomatoes, however, it has been very common in some seasons, and caused quite a number of the plants to die right off. When the plants were about full grown, and coming into bearing, they would suddenly wilt and collapse. About the beginning of December, 1909, some potato plants were observed to have prematurely decayed, their leaves becoming wilted and shrivelled up. On slitting up the brittle stem, it was found to have rows of black bodies inside, varying in size and shape from that of a pea to a grain of wheat. The one photographed was about three-eighths of an inch in length, and covered in parts with a whitish mould. (Fig. 100.) This is known as the sclerotium stage of the fungus, and consists of fungus filaments, tightly twisted around each other into a compact, dark-coloured mass, which, however, is white in the interior. (Fig. 101.) This is the resting-stage of the fungus to carry the disease over the winter, and when ripe the black bodies fall to the ground, where they are able to withstand adverse conditions until the time for their further development arrives. At present these bodies are being kept on moist earth under a bell-jar, but, so far, no change has taken place.

(Plate XXX.)

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## X.—STRINGY ROT.

( *Armillaria mellea* Vahl.)

Occasionally the potato is found to be more or less covered with brownish strands, like so many cords, and they may even grow beyond it to a length of six or seven inches, as shown in the accompanying photograph. (Fig. 102.) These coarse, brown strands belong to a fungus which grows on the roots of numerous plants, and eventually causes their death, so that it is popularly known as the "tree-killing fungus." It not only attacks forest and fruit trees, but also bushes such as the gooseberry and raspberry, and even herbaceous plants such as the potato.

## NATURE OF FUNGUS.

By means of these strands it is able to spread in the soil, and pass from one plant to another. In one place, where this fungus was found on the potato, it likewise occurred on the roots of apple trees and vines, and on inspecting some of the "bush drains" made from twigs of the wattle, I found them to be just a perfect breeding ground for the fungus.

When these fungus strands reach the root of a living tree, they are able to bore through the outer bark into the soft bark, and there to spread out like a fan into a mass of soft white filaments, which invade the living layer and destroy it by feeding upon it. These filaments may spread between the bark and the wood, either up the stem or along the healthy roots, and in course of time the tree dies, because the roots no longer serve their proper function and nourish it. In the case of the potato these white filaments are formed beneath the skin, and the flesh becomes brown, because the cells are killed by the fungus.

Towards the end of the growing season, and when the available nourishment has been largely appropriated by the fungus, it may develop fruiting bodies in the form of a well-known toadstool, recognised as the Honey Agaric, and scientifically named *Armillaria mellea*.

## HOW IT AFFECTS THE POTATO.

Just as this fungus may pass from the roots of native trees to cultivated trees, so in newly cleared ground the potato may be attacked by it, and once having gained a footing it is difficult to eradicate. The cord-like strands at first tightly envelop the potato (Fig. 106), and gradually the white mycelium is formed, which penetrates the skin. (Fig. 107.) There it ramifies among the starch-cells and brings about their decay and death, so that the flesh of the potato has a brown appearance, intermixed with the white filaments of the fungus. Finally the potato may become completely destroyed, and shrivel up into a dry, decayed mass. (Fig. 108.) This disease has been recorded from Tasmania and New South Wales, as well as from Victoria; but it is so conspicuous from the brown cord-like strands that it is readily detected, and the disfigured tubers should at once be rejected and destroyed.

One tuber, quite firm and affected with stringy rot, was found among a number of healthy ones growing on the same plant. The decayed roots of a eucalypt were observed in the soil in contact with it, and not only were the black strands of the *Armillaria* on the skin of the potato, but the white fungus had penetrated inside, mottling it all through, as shown in Fig. 108.

## PREVENTIVE MEASURES.

This is a difficult disease to deal with, because it lives in the soil in decaying roots, &c., and readily passes to any fresh succulent growth. Well-drained soil is inimical to it, and the ground should be thoroughly cultivated, so that all decaying roots are brought to the surface and burned before planting.

(Plates XXX., XXXI.)

## XI.—BROWN FLECK, OR INTERNAL BROWN SPOT.

This disease is generally called brown fleck with us, because the affected potatoes when cut across show brown specks in the otherwise sound flesh (Figs. 103, 104, 105), being to all outward appearance quite sound, though the skin is generally somewhat rougher. It is not a brown rot, for such potatoes keep all right, only when boiled the brown specks become quite hard and impair the edible qualities of the potato.

There is a disease mentioned in the *Journal of the Board of Agriculture* for April, 1910, known as "Sprain" in potatoes, which seems to be increasing. The brown spots are found when the potato is cut across, and on cooking the potato these spots can be picked out like pellets. It is usually found on a gravelly, but sometimes on a sandy soil, and quite absent on a stiff soil. The disease is not conveyed by the seed, and altogether it agrees with the one we are now considering.

It was first recorded in Britain as an "internal disease" in 1898, and in America and Australia in 1895; but, like the Irish Blight, it probably exists wherever the potato is cultivated. Why the disease is called "sprain" is not quite clear. It is unfortunate, at any rate, as it conveys the impression that it is due to some mechanical cause, such as a twist or an overstrain.

It is not a parasitic disease, for no organism of any kind has been found associated with it, and it cannot be transferred to a healthy tuber. Diseased pieces have been inserted into sound potatoes without producing any effect, and diseased tubers have been planted from which healthy ones were produced.

### MICROSCOPIC APPEARANCE.

If a microscopic examination is made of the brown tissue, the majority of the cells are found to have collapsed, and there is a marked deficiency of starch grains, as compared with the surrounding healthy tissue. Although in very bad cases, where the spots have run together and have even extended to the skin, and might be mistaken on a superficial view for Irish Blight, yet there are no fungus filaments present. Even with the naked eye the difference may be detected, for, when a "flecked" potato is sliced and placed in a moist chamber, the slices become dry, whereas a "blighted" potato not only produces the fructification of the fungus, but the slices remain moist.

In the brown diseased tissue the middle lamella of the cell-wall is stained by phloroglucin, while the healthy cell-walls are unaffected. This indicates that the walls of diseased cells have become lignified or woody.

When malachite-green is used instead of phloroglucin, the middle lamella of the diseased cells is deeply stained, and the brown granular contents also assume a green tint.

### CAUSES ASSIGNED.

Various causes have been assigned for its appearance, but none of them are sufficient to account for it. The soil and the weather, and even the manure, have all been brought forward as probable causes, but none of them have been found to hold good in every case. It is certainly most prevalent in light loam or sandy soils, but it is observed here that it usually occurs in that portion of the field where water lodges. Rapid growth is said to favour the disease, since the small potatoes or seconds are seldom affected, such potatoes being produced late in the season when growth is slow.

It is also attributed to a want of lime or potash in the soil, but here again it has occurred where these ingredients were not lacking. Dry weather, associated with poor growth, has also been mentioned; but in Germany damp weather is said to favour it, although under such conditions it does not



always appear. It has been observed that if stable manure is applied immediately before planting, it does not occur, but if applied earlier in the autumn, then it is liable to appear.

Some varieties are more susceptible than others, but, on the whole, it must be regarded as a physiological trouble.

#### SPRAIN OR STREAK DISEASE.

In the *Journal of Agricultural Science* for September, 1910, there is an article by A. S. Horne on "The Symptoms of Internal Disease and Sprain (Streak Disease) in Potato," and he distinguishes between the blotch-like and streak-like markings in the flesh. The former, with rusty-brown spots, constitutes the disease known here as "Brown Fleck," and the latter is called "Sprain" in Britain, on account of the streaky appearance. The internal disease varies in appearance from mere brown specks to dark blotches, which may or may not form a connected system. It is interesting to notice that the skin was discoloured in places, with small areas of brownish tissue immediately beneath. The affected cells still retain their starch, but the protoplasm is of a brownish colour, owing to the formation of a gummy substance within the cell. Very young tubers may be affected with this disease well developed, and even at this early stage no organism of any kind was detected in the brown areas.

In the case of Sprain, or Streak-disease, the streaks are quite distinct from the blotches, and frequently form a series of curves one within the other. The streaks in tubers badly affected often extend to the margin, and the diseased cells may sometimes be followed right up to the cork, or a lenticel, or a slight wound. Several experiments were carried out to test if the disease can be transmitted through the seed, and in every experiment it was found that a certain proportion of tubers were affected. But when potatoes were kept in store, neither of these diseases spread, the markings remaining stationary in the affected, and not appearing in sound tubers.

I had the privilege of discussing the subject of "sprain" with Dr. J. H. Wilson, of St. Andrew's University, when visiting Australia recently as a member of the Scottish Agricultural Commission. He found as the result of his investigations that sprain did not occur in heavy soil overlying volcanic rock, but generally in light soils over sandstone. There was also a certain class of potato less liable to sprain than others, such as the coarser kinds of poorer quality. On the whole, he considered the disease to be due to a check in growth, since it only occurs in certain seasons, and that check in growth is associated with a lightness of the soil. The application of kainit had a marked effect in lessening the amount of sprain.

#### PREVENTIVE MEASURES.

Where a disease, as in this instance, is due to physiological causes, there is no single factor which will account for it, but there is probably a combination of circumstances producing it. In the absence of a definite cause, no definite recommendations can be given for avoiding it, but suggestions may be made which will tend to lessen it.

1. It is certainly not advisable to use affected potatoes for seed, since, whether the disease is transmitted by the seed or not, the presence of it indicates that at least it is a susceptible variety.
2. The use of a potash manure, such as kainit, has been found in Scotland and elsewhere to have a marked effect in decreasing the disease, and may therefore be recommended.

(Plates XXX., XXXI.)

**"MISSES" IN THE POTATO CROP.**

It is not an uncommon occurrence to find in a potato field that, although the rows have been regularly planted with "sets" which to all appearance seemed sound and healthy, yet, when the shoots appear above the ground, there are many noticeable gaps among them. It is not always easy to account for this, for the soil may be generally equal throughout, and the conditions equally favourable, so that the only reasonable explanation is that the "seed" must have been faulty in some way. The reduction in the total yield is sometimes so great that it becomes a matter of importance to determine how far the losses from this cause may be prevented.

I have had occasion to investigate a good many cases where the "misses" were very conspicuous, and, while it has not been possible to determine the actual cause in every instance, yet sufficient evidence has sometimes been obtained to justify putting it on record here. Of course, when the "set" is found to have rotted away, there is no difficulty in accounting for the deficiency, but, when it is seemingly alike in every respect to those which have sprouted properly, the case is different.

**THREADY EYE, NEEDLE EYE, OR SPINDLE DISEASE.**

A commonly occurring cause of missing is that of "thready eye," where the "eyes," instead of developing robust and healthy shoots, produce numerous slender threads, as shown in Fig. 96. This tendency to produce the stringy growths of a pale colour receives in France the appropriate name of *Filosité*. This is a disease the exact cause of which is unknown. It has been attributed to a parasitic fungus, but no definite organism has been found causing it. There seem to be various causes at work, and bad or defective nutrition is the chief, leading to marked poverty of starch in the tubers.

Mr. Seymour, our potato expert, has been investigating this disease, and he has been in communication with V. La Bergerie, of France, and I am able to present their views.

When ordinary potatoes were planted in very dry soil, so that only small and unripe tubers were produced, and the plants died prematurely, the entire crop suffered from this disease.

Then, again, planting in a cool, moist soil, with exuberant vegetation at the start, followed by a sudden stoppage owing to drought, yielded a crop suffering considerably from this disease, even up to 80 per cent.

The action of manures has not been found to have any appreciable influence on the disease, but the presence of lime has diminished it considerably, sometimes as much as 50 per cent. Lime affects the flavour of the potato very unfavorably, and Bergerie has suggested that, in order to avoid the disease, seed potatoes could be grown in calcareous soils and potatoes for human consumption on sandy soils.

This disease is generally considered to be due to reduced vitality in the "seed," or degeneration, and accompanying this a want of capacity to elaborate the diastase or ferment necessary to render the starch available for the growing plant, while the influence of drought would only be a secondary factor.

Where this disease is very common, a change of seed potatoes from a different kind of soil should be tried, and, of course, affected potatoes should not be planted.

The grower recognises the presence of "thready eye" in a potato in various ways—

1. If a potato has sprouted, the slender, thread-like, pale-coloured shoots indicate the disease. (Fig. 96.)
2. Or by the production of minute tubers close to the "eye" without any shoots at all. (Fig. 149.) These are called "mules" by the French.
3. But even in cutting the potato for seed there is internal evidence of it. There is not only the usual vascular ring to be seen, but a regular network of dark streaks throughout the entire flesh of the potato, generally radiating from a dark central core, as in Fig. 83.

#### RHIZOCTONIA.

Numerous instances have come under my notice where this disease is responsible for "misses." The black specks are so common on potatoes supplied for seed, that it is difficult to get any quantity free from them, and they have been so long regarded by growers as of no importance that tubers so affected are regularly planted. The Carmans are particularly liable to this disease, and, as already shown, it may attack quite young plants at the collar, and cause them to rot away without forming any tubers. To get a regular and even crop without numerous gaps here and there, it will be necessary in the future to avoid planting potatoes with the black specks upon the skin, which stand out so conspicuously, particularly when the potatoes are wetted.

#### PRACTICAL MEASURES.

There are at least two ways in which a potato planted may fail to grow, quite independent of any organism rendering it diseased. It may either remain dormant, and send out no shoots, or the shoots may be so feeble in their growth that they soon die down. This failure to grow is usually attributed to degeneracy of the potato, but an interesting experiment by the Curator of the Royal Gardens, Kew, showed that this is not necessarily the case. He placed some tubers, which refused to sprout when exposed to the ordinary conditions, in one of the forcing pits, where the average temperature was about 70 degrees Fahr., and in due course all the "eyes" at the crown or apical end of the potatoes sprouted. They were then planted in the usual way, and produced a normal crop. The sluggish tuber required the stimulus of heat to render the diastase active and convert the starch into sugar for the use of the growing plant.

When the "sets" are too mature they frequently do not decay, and thus there may be numerous gaps in the crop owing to this cause. To insure the production of strong shoots, and thus prevent the possibility of misses, and at the same time insure an early crop, with the likelihood of freedom from disease, the process of "greening" or "boxing" should be adopted. Any weakness in the seed potatoes, such as "thready eye," can then be detected, and only sound healthy tubers need be planted.

## LENTICELS.

Minute warts may often be seen with the naked eye on the surface of the potato, and these are the breathing pores or lenticels, already shown in Fig. 44. When the tubers are kept very moist, as in a wet summer, these openings may assume a white, mealy appearance. (Fig. 150.) The excessive moisture causes the corky tissue of the skin to swell up at these openings, and the outermost corky cells to separate. On digging, the tubers are often seen to be covered with white spots, which are puzzling to the grower. These are the loose cells which are pushed out of the pores in great abundance, and form the white, fluffy material at the surface.

The protective covering of cork forming the skin of the potato has to be interrupted at various points to admit air, and this at the same time gives access to various fungi, which ramify among the tissues and destroy them. But the white fluffy spots scattered over the surface of the potato are not in themselves of any serious import, although they have been mistaken for fungi, and the appearance is specially noted here to allay the fears of the anxious grower.

(Plate L.)

## NOTE.

O. 16.—In the report of the botanist, Dr. G. P. Clinton, of the Connecticut Agricultural Experiment Station for 1909–10, and issued in June, 1911, there is an article on the Oöspores of Potato Blight, *Phytophthora infestans*.

He has succeeded in producing the oöspores in artificial cultures by securing favorable strains of the fungus, and employing suitable media. "The one medium that has stood alone, so far as production of oöspores is concerned, is our oat juice agar. Without this, apparently, we would never have produced perfect oöspores in cultures."

The production of oöspores is very variable, and on account of their comparative scarcity, the different steps in their development have not been closely followed. The female reproductive organs, or oögonia, are much more common than the male reproductive organs, or antheridia, which are frequently missing, but they are both shown quite distinct in the photographs, and are just as perfect, although not so abundant, as any produced in allied forms, such as *Phytophthora phaseoli*.

Although the resting-spores or oöspores of this fungus have been produced in artificial cultures, it must not be inferred that they are also freely produced in nature, for it only shows that the ancestors of this fungus possessed the power of sexual reproduction. In fact, Clinton recognises that the discovery is more of scientific than of practical interest, for he concludes as follows:—"As the potato blight, so far as is known in nature, carries over from one season to another only through the vegetative mycelium in the tubers, it may be that continued asexual propagation of the fungus in this manner has also resulted in its loss of sexual vigour, especially of the antheridia."



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## PLATE I.

## POTATO BLIGHT.

Fig.

1. Snowflake variety of potato with Irish Blight fungus on the surface in the form of numerous white delicate patches towards stalk end.





1

SNOWFLAKE WITH IRISH BLIGHT





## PLATE II.

## POTATO BLIGHT.

Fig.

2. Section of same showing the flesh beneath the skin browned and destroyed by the fungus, hence the name of "Brown Rust." The fungus entered at the stem and is progressing towards the crown.





2

INTERNAL VIEW OF SNOWFLAKE WITH IRISH BLIGHT





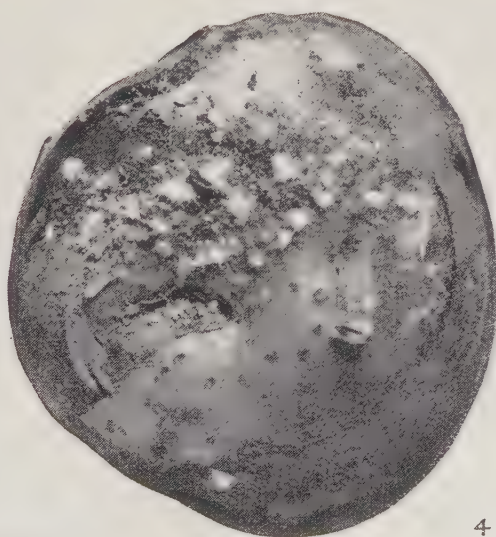
## PLATE III.

## POTATO BLIGHT.

Fig.

3. Upper surface of leaf showing effects of Blight.
4. Potato with dense white mould of Irish Blight fungus. Shortly afterwards it was overrun with a luxuriant white mould of *Fusarium*.













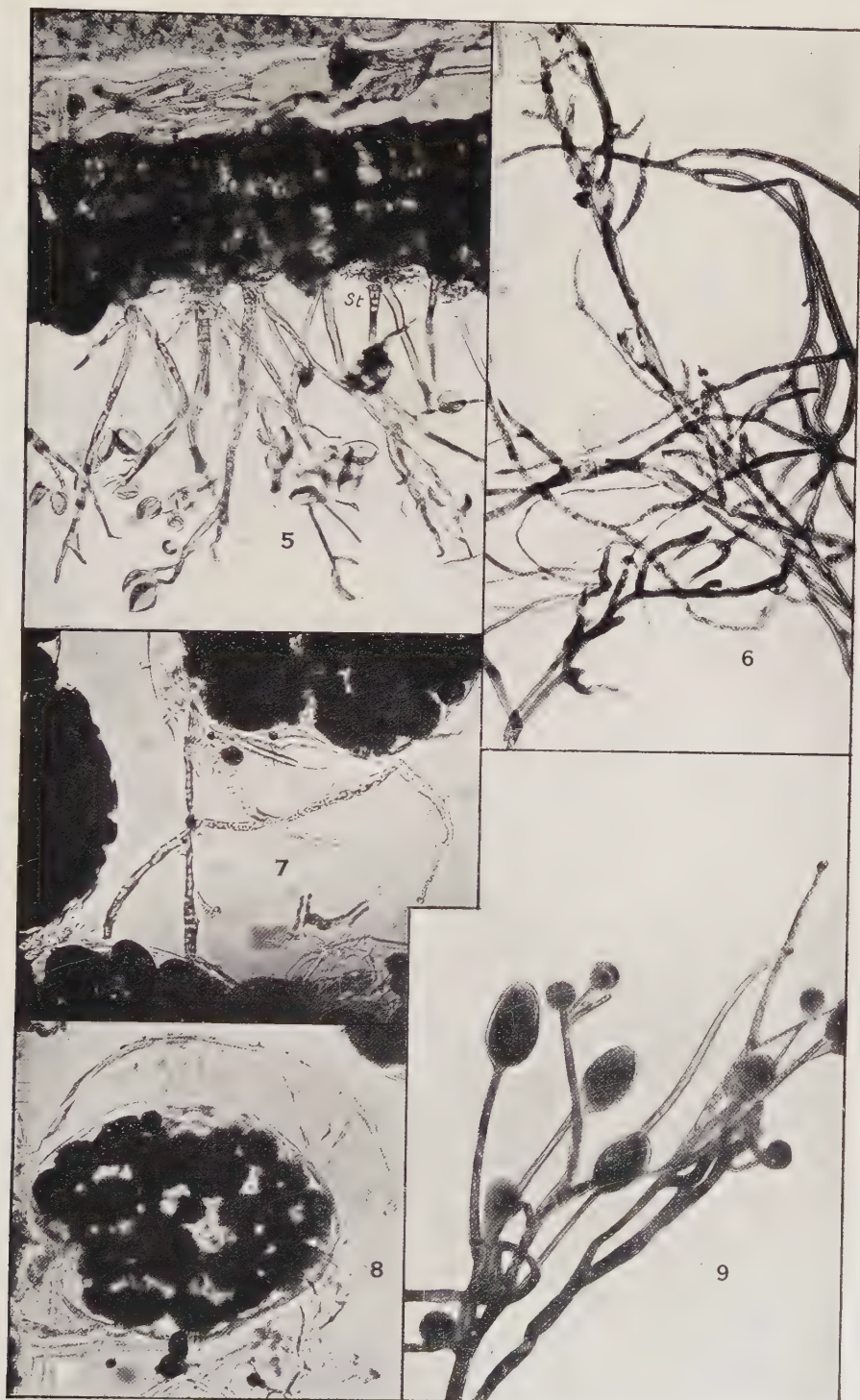






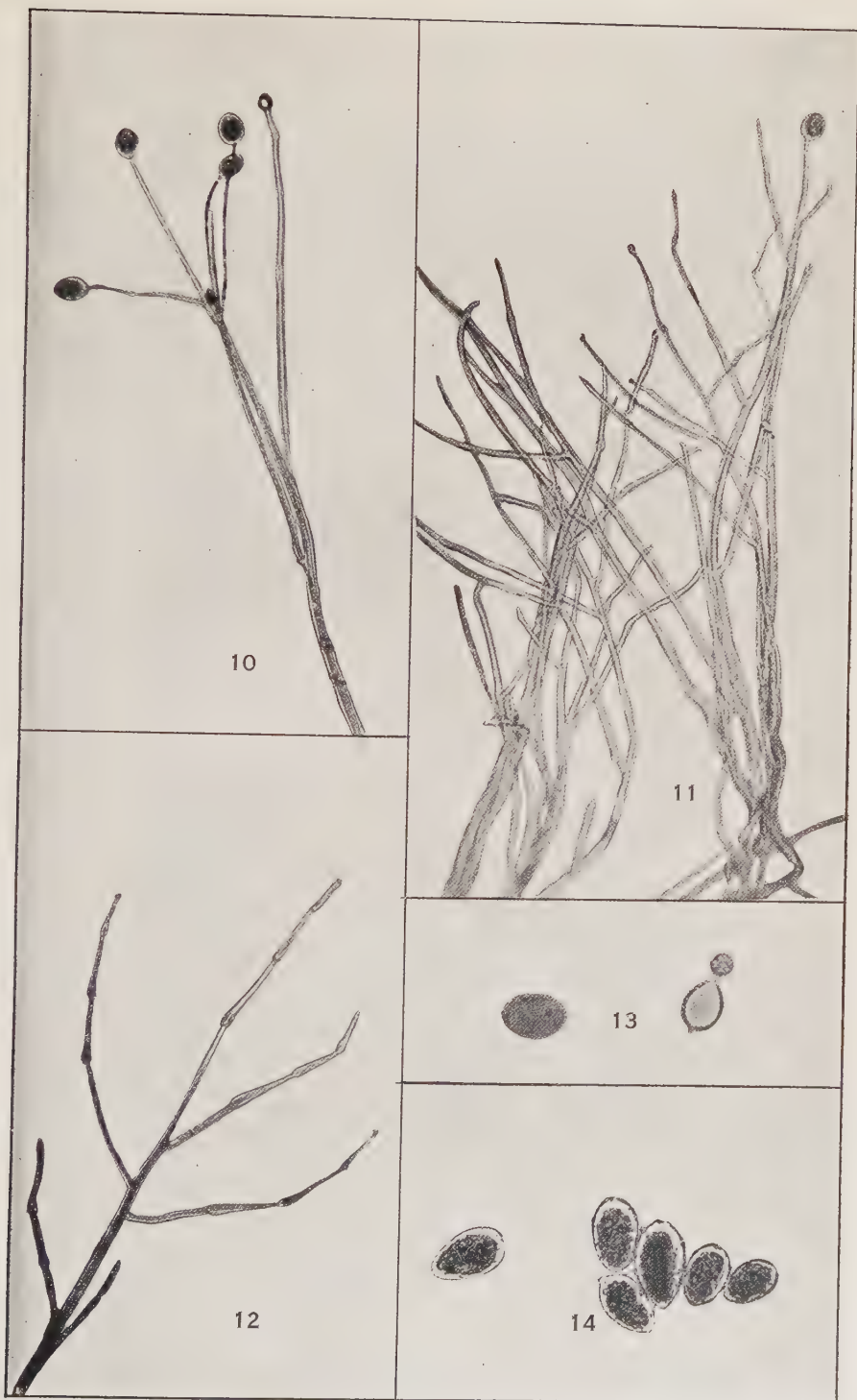
PLATE V.

POTATO BLIGHT.

Fig.

- |   |   |     |
|---|---|-----|
| 10. Fructification with sporangia attached, showing four branches from main stem  | × | 150 |
| 11. Fructification shown arising from mycelium at base .. .. .  | × | 300 |
| 12. Fructification, showing mode of branching, with branches irregularly swollen at intervals where sporangia were detached. As many as eight swellings have been found on one branch .. .. . | × | 300 |
| 13. Sporangium with contents dividing, and another from which the swarm-spores have escaped, showing one at opening .. .. .   | × | 30  |
| 14. Group of sporangia with the contents breaking up .. .. .  | × | 30  |









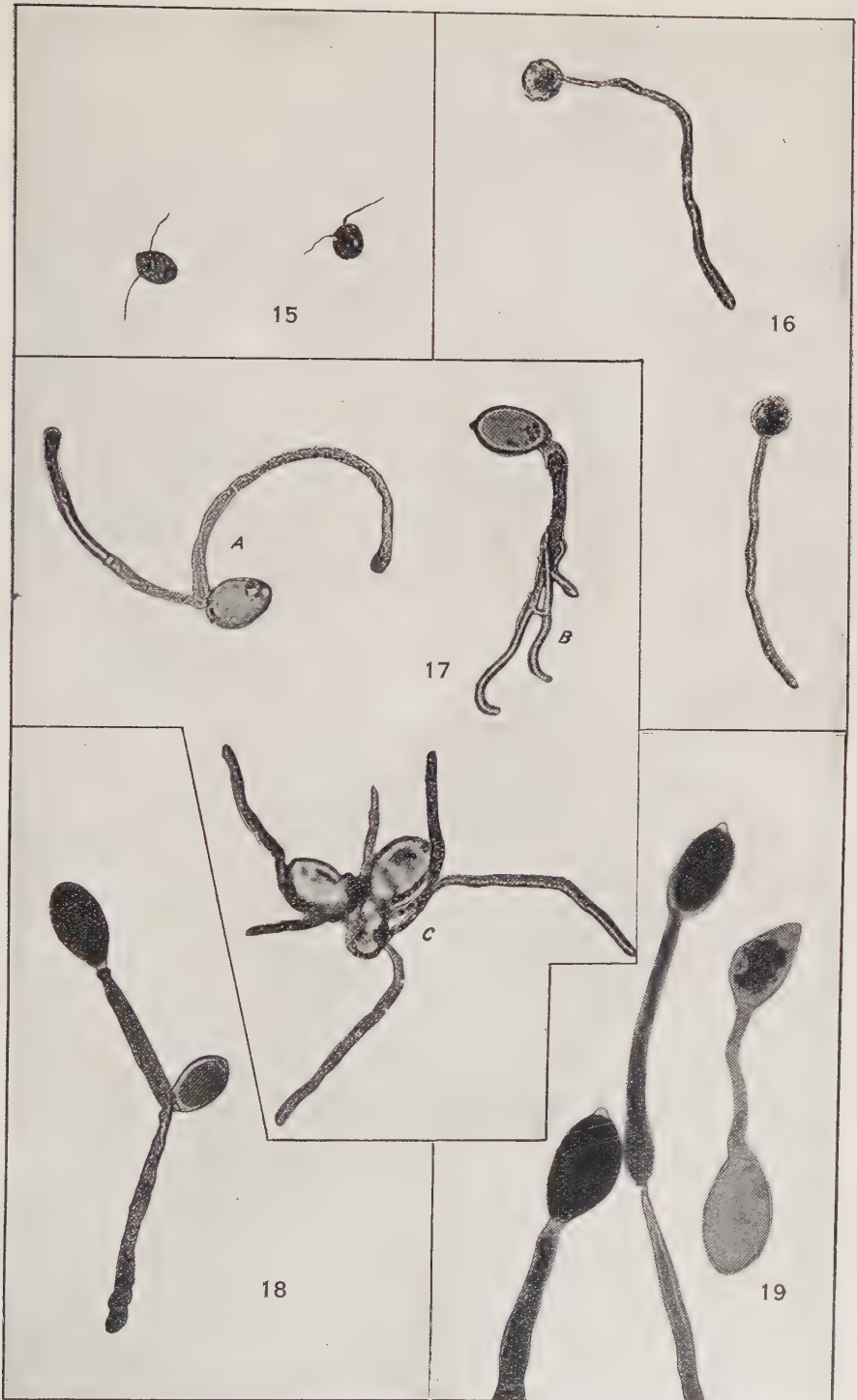
## PLATE VI.

## POTATO BLIGHT.

Fig.

- |   |    |    |    |     |
|---|----|----|----|-----|
| 15. Free swarm-spores with cilia swimming about in the moisture   | .. | .. | ×  | 500 |
| 16. Swarm-spores come to rest, with cilia dropped and spore putting forth germ-tube   | .. | .. | .. | ×   |
| 17. Conidia directly germinating—A. with two germ-tubes unbranched; B. with one germ-tube giving rise to delicate branches; C. a group of three variously germinating | .. | .. | .. | ×   |
| 18. Sporangia both at end and side of branch  | .. | .. | .. | ×   |
| 19. Terminal sporangia on branches  | .. | .. | .. | ×   |
| Conidium sprouting and forming a secondary conidium at its free end   | .. | .. | ×  | 500 |









## PLATE VII.

## EARLY BLIGHT.

Fig.

20. Young leaflets of potato affected by the Early Blight, showing the formation of small discoloured spots, which sometimes fall out and leave a hole.
21. Mature leaf of potato, showing large dry spots due to the growth of the fungus.





EARLY BLIGHT OF POTATO  
YOUNG AND MATURE LEAVES AFFECTED



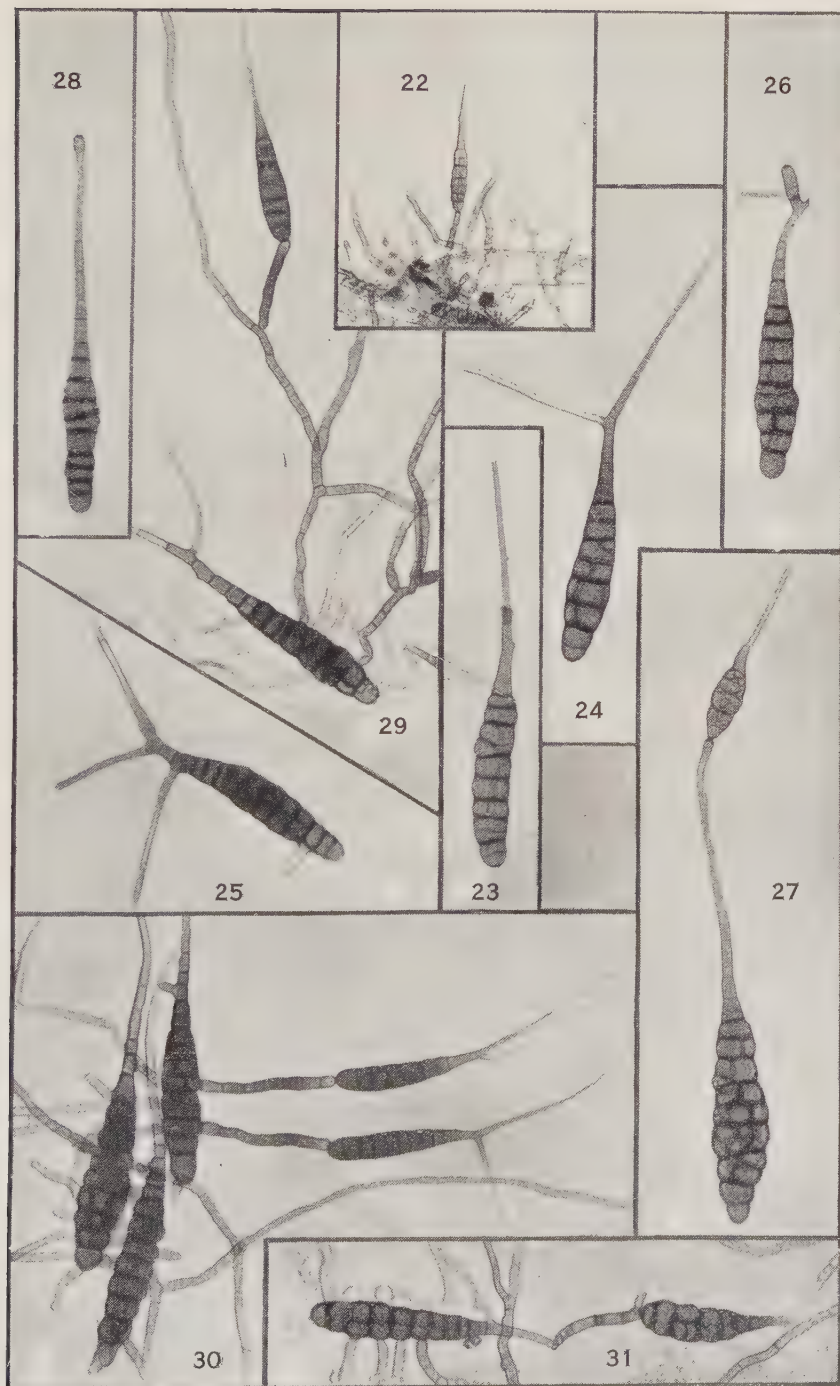


## PLATE VIII.

## EARLY BLIGHT.

Fig.

- |   |    |    |   |     |
|---|----|----|---|-----|
| 22. Conidia-bearers and conidia of the fungus growing on the leaf   | .. | .. | × | 100 |
| 23, 24, 25. Conidia with one, two, and three beaks  | .. | .. | × | 250 |
| 26. Conidium with one-beak, upon which a cup-shaped conidia-bearer has been formed, the conidium shown in Fig. 23 having fallen from it   | .. | .. | × | 250 |
| 27. Chain of two conidia. In the larger the single terminal beak has become modified so as to serve as a conidia-bearer, being terminated by the characteristic cup-shaped apex | .. | .. | × | 250 |
| 28. Conidium showing the modification of the single terminal beak into a conidia-bearer with the cup-shaped apex  | .. | .. | × | 250 |
| 29. Conidium germinating in a decoction of potato-leaf, showing the formation of mycelium, in turn giving rise to a conidia-bearer and conidium                                 | .. |    | × | 250 |
| 30. Conidia germinating in a decoction of potato-leaf, one of them producing two conidia-bearers, each bearing a conidium with two beaks  | .. | .. | × | 250 |
| 31. Conidium germinating in potato-leaf decoction, a secondary conidium being formed at the apex of the conidia-bearer arising from the terminal beak                           | .. |    | × | 25  |







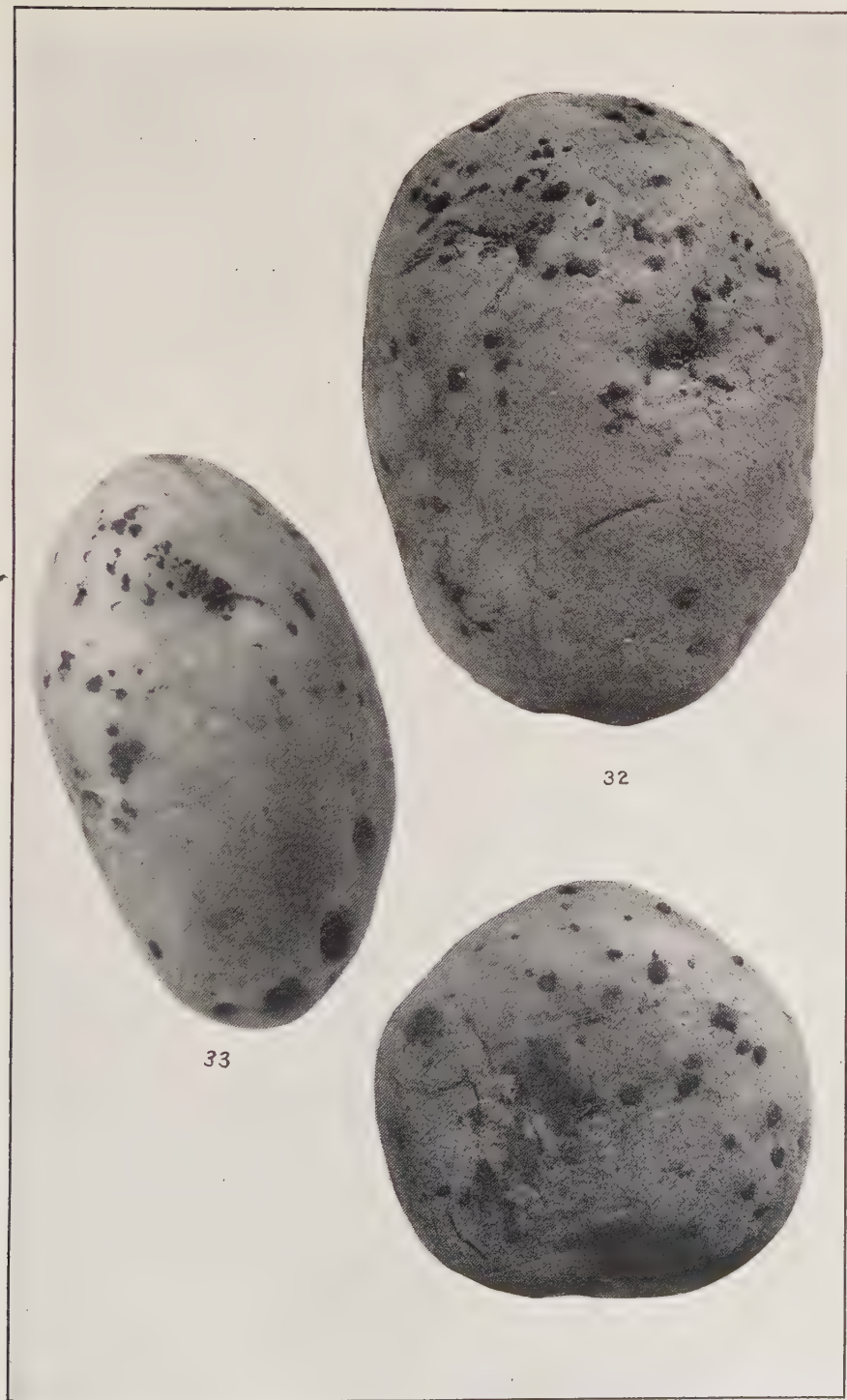


## PLATE IX.

## RHIZOCTONIA ROT.

Fig.

32. Sclerotia on two potatoes from Tasmania, generally distributed over the surface, and of various sizes.
33. Sclerotia on potato from South Australia, sometimes confluent.



Nat. Size

RHIZOCTONIA, SHOWING SCLEROTIA





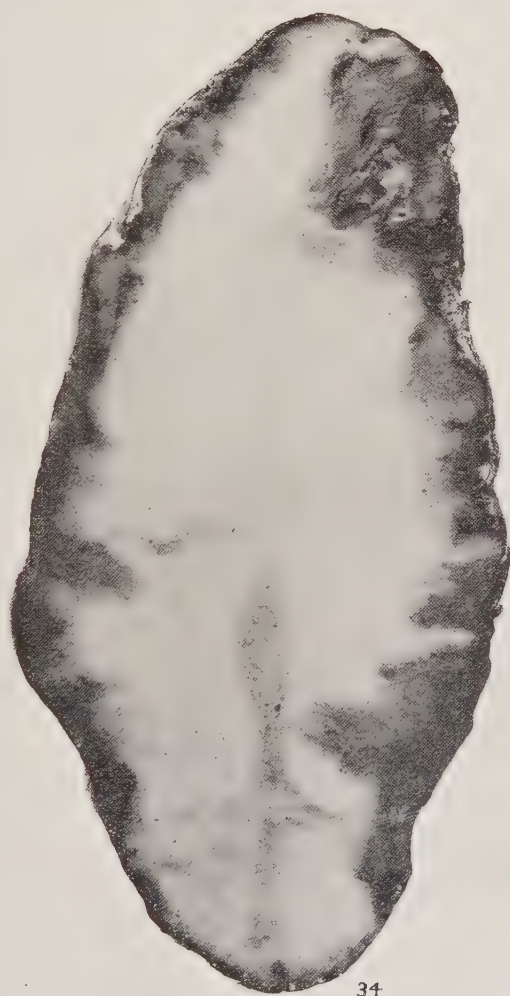


## PLATE X.

## RHIZOCTONIA ROT.

Fig.

34. Section of Tasmanian potato, showing what looks like "Brown Rust," due to *Rhizoctonia*. The filaments of the fungus were jointed and no potato blight developed after keeping moist for a considerable time.



34

SECTION OF POTATO  
WITH BROWNING DUE TO RHIZOCTONIA

Nat. Size







## PLATE XI.

## RHIZOCTONIA ROT.

Fig.

35. Three young potato plants, dying from effects of Rhizoctonia.







## PLATE XII.

## RHIZOCTONIA ROT.

Fig.

36. Section through sclerotium on surface of potato, showing the tangled mass of jointed hyphæ composing it . . . . . × 170
37. Section of sclerotium in flesh of potato, extending  $\frac{1}{2}$  inch beneath surface. It is sometimes stated that the sclerotium is always superficial . . . × 170
38. Jointed hyphæ inside potato spread out . . . . . × 170
39. Hyphæ immediately beneath corky cells of skin of potato, as seen from the surface . . . . . × 170
40. Hyphæ ramifying among starch-cells of potato . . . . . × 500



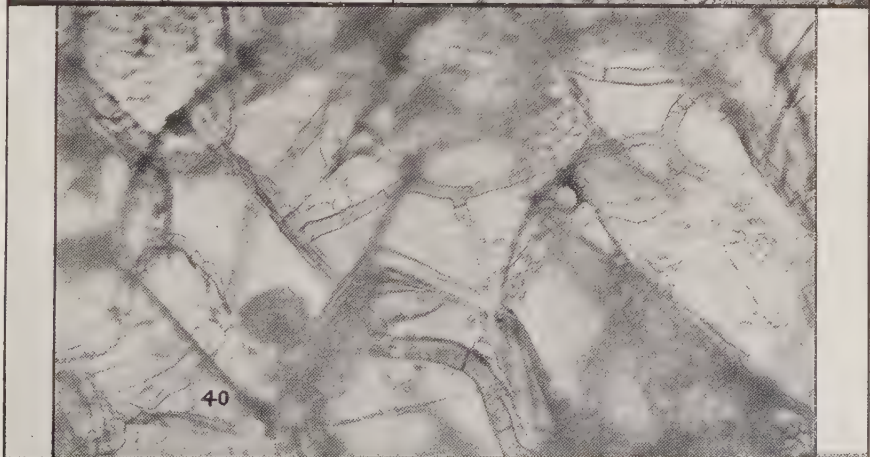
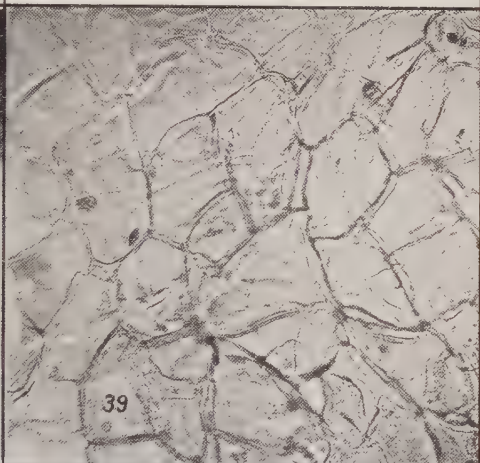
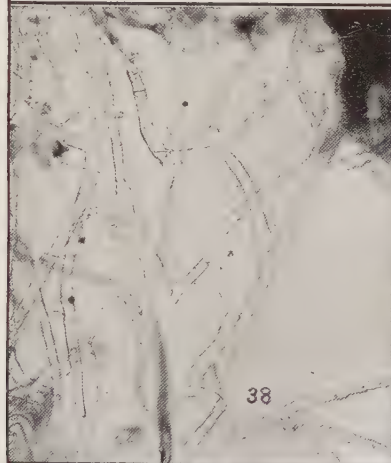
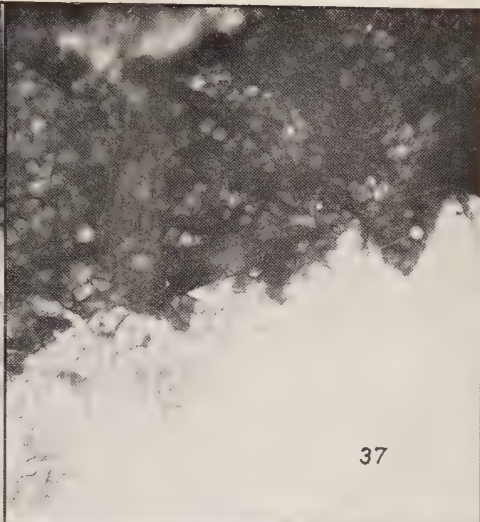
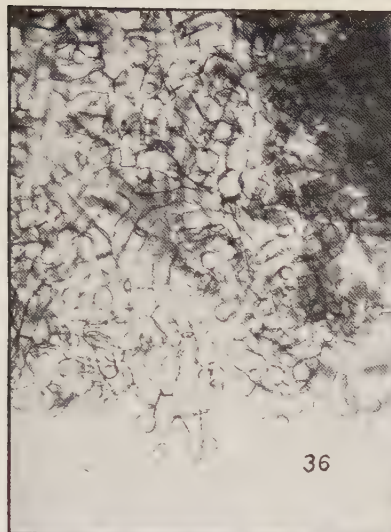


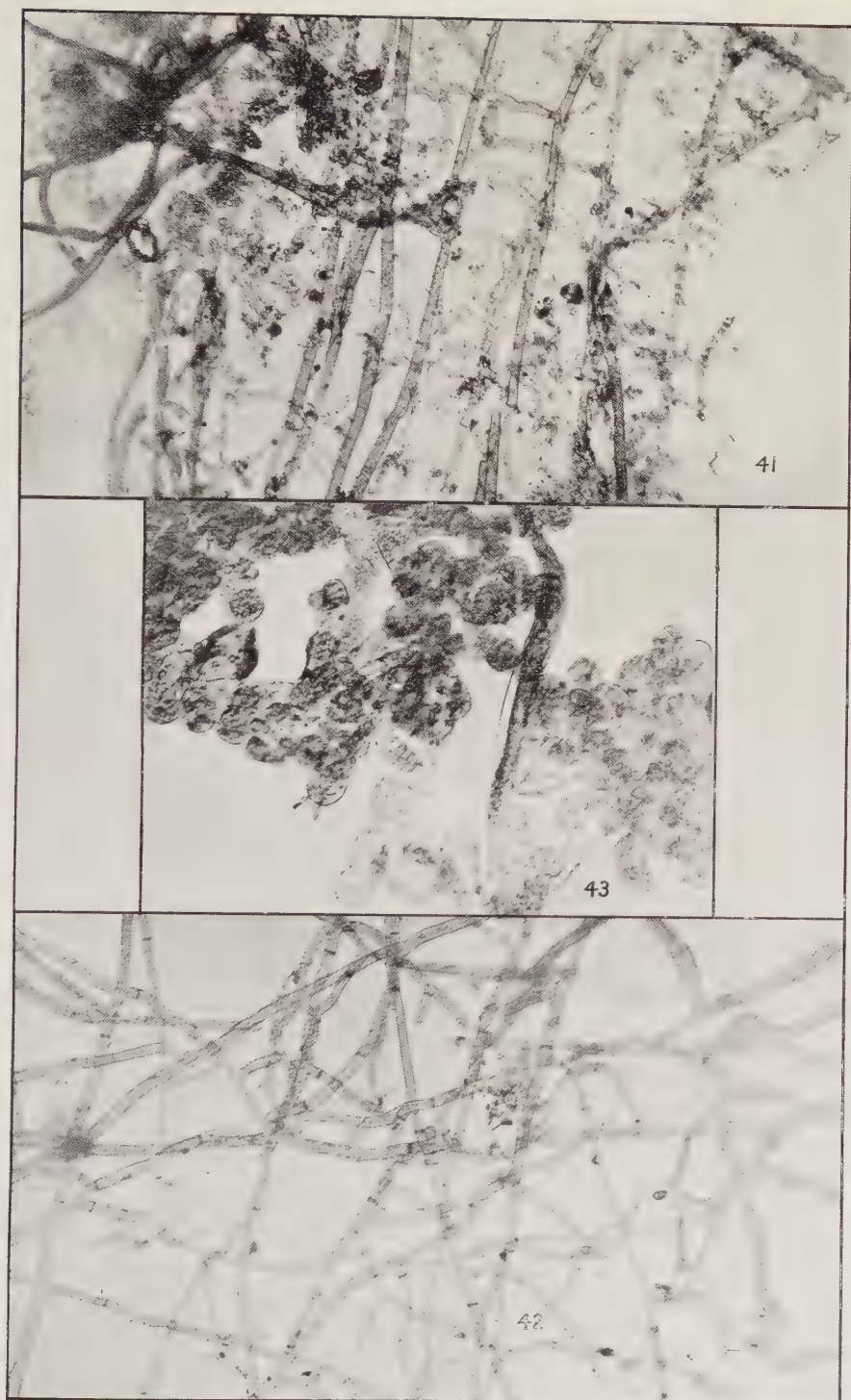




PLATE XIII.

RHIZOCTONIA ROT.

Fig.									
41.	Hyphæ on root	..	..	..	..	..	..	..	× 170
42.	Hyphæ on surface of stem above ground	..	..	..	..	..	..	..	× 170
43.	Conidial stage, showing oval terminal cells, one of which bears two young conidia (conidia not shown at end of basidia)	..	..	..	..	..	..	..	× 500









## PLATE XIV.

## POTATO SCAB.

Fig.

44. Cross-section of healthy skin of potato showing lenticels or breathing pores (after Sorauer) .. .. . Magnified
- k.* corky cells of skin; *st.* starch-containing cells beneath skin; *a.* lenticel just beginning to form; *f.* lenticel formed and filled with loose mealy cells.
45. Potato with "blister" due to Eel-worm, some of them broken and forming scab-like depressions on the surface .









## PLATE XV.

## POTATO SCAB.

Fig.

- |     |   |    |    |    |    |    |         |         |
|-----|---|----|----|----|----|----|---------|---------|
| 46. | New Zealand Pink Eye, showing blisters broken and the tubers variously affected | .. | .. | .. | .. | .. | ..      | Reduced |
| 47. | Young affected tubers still attached  | .. | .. | .. | .. | .. | Reduced |         |









## PLATE XVI.

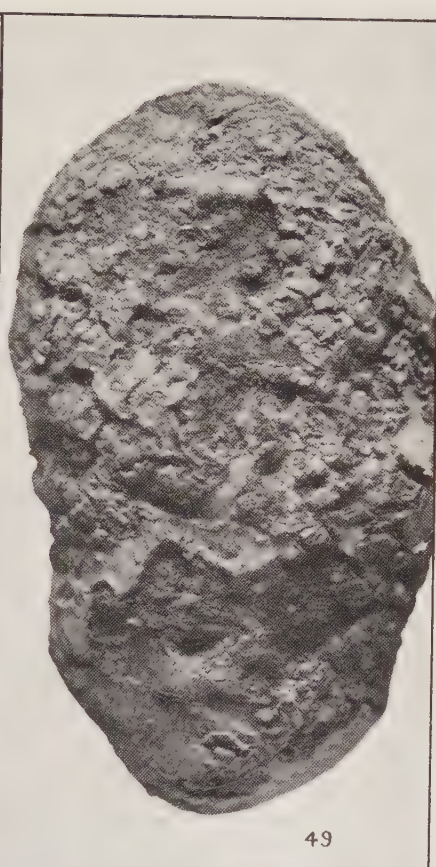
## POTATO SCAB.

Fig.

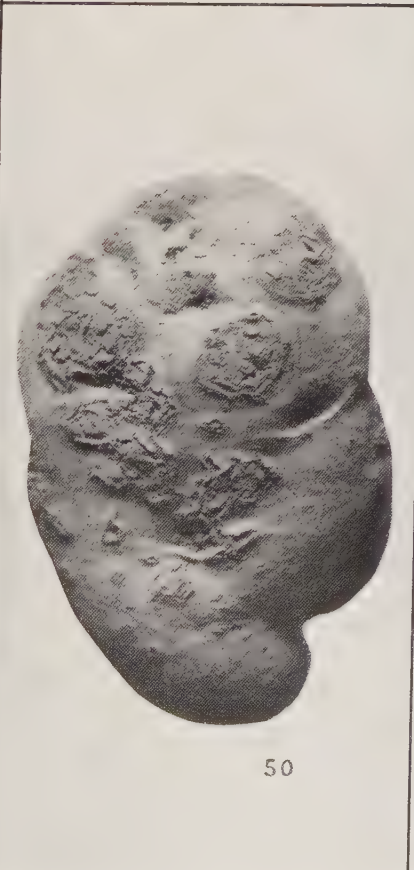
48. Potato with blisters,—broken and unbroken.
49. Potato with most of the surface covered by broken blisters.
50. Potato with broken blisters in isolated patches and presenting a “scabby” appearance.
51. Carman No. 1 potato with broken blisters run together, taken from sample which was treated at Bunyip in 1905 and produced practically a clean crop, while the untreated were largely “scabby,” as shown in Plate XVII.



48



49



50



51





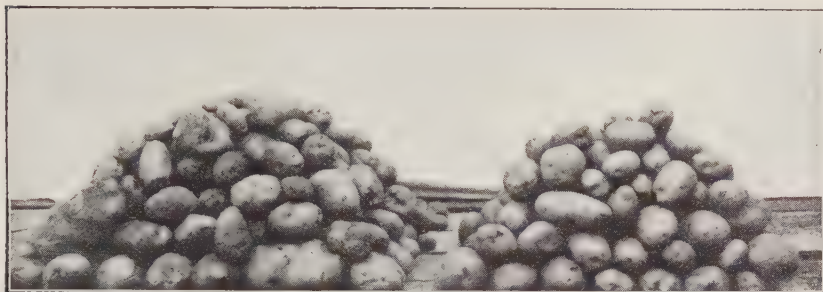
## PLATE XVII.

## POTATO SCAB.

Fig.

- 52. Produce of "scabby" seed untreated—a larger proportion scabbed than clean.
- 53. Produce of "scabby" seed treated with corrosive sublimate—all practically clean.
- 54. Produce of clean seed infected by contact with "scabby" seed and untreated—about as many scabbed as clean.



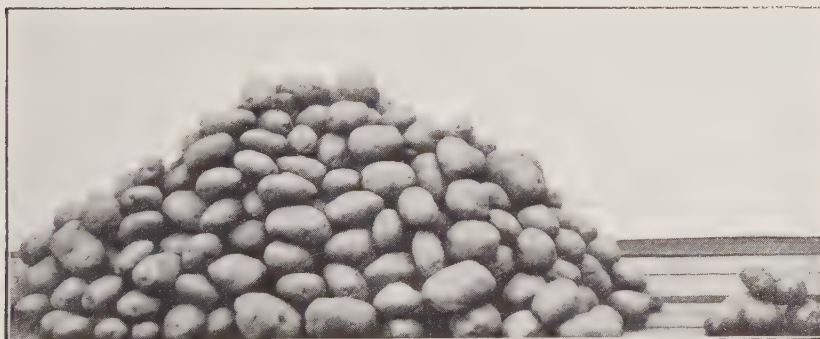


52

SCABBY SEED UNTREATED.

77 lbs. scabbed.

58 lbs. clean.



53

SCABBY SEED TREATED WITH CORROSIVE SUBLIMATE.

195 lbs. clean.

2 lbs. scabbed.



54

Reduced

CLEAN SEED INFECTED BY CONTACT—UNTREATED.

84 lbs. scabbed.

89 lbs. clean.

SCABBY SEED TREATED AND UNTREATED






## PLATE XVIII.

## POTATO SCAB.

Fig.

55. Longitudinal sections of potatoes showing little round cysts beneath the skin and extending completely round—these are the female eel-worms distended with eggs.
56. Section of “scab” caused by eel-worm, showing layer of flat corky cells between the top or outside diseased and the inner healthy portion. The irritation caused by the eel-worm has brought about a development of cork beneath the broken surface  × 100
57. Potato with black warty excrescences at “eyes,” associated with potato moth, and no fungus or eel-worm present
58. Black “scabs” run together due to *Rhizoctonia*.

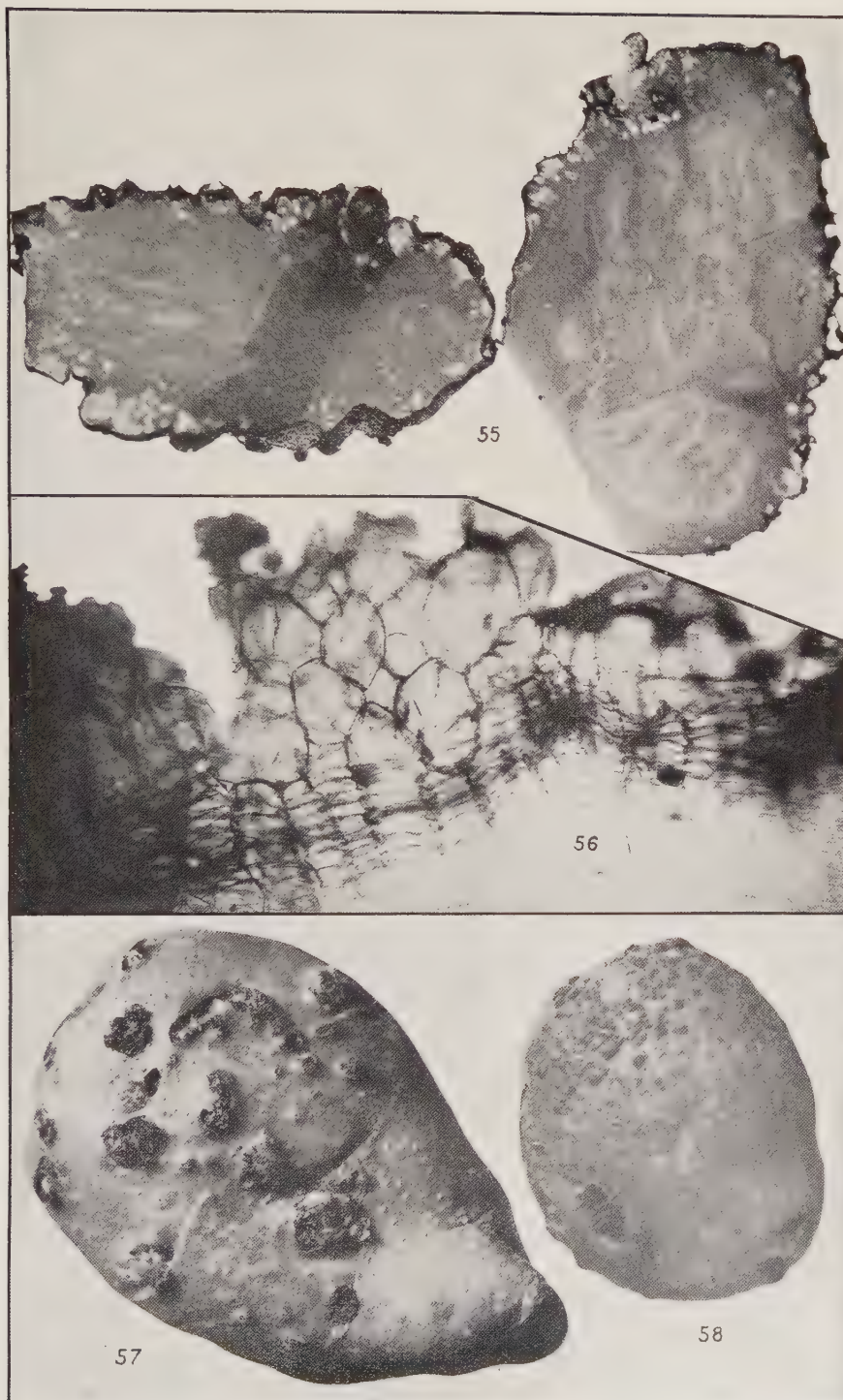






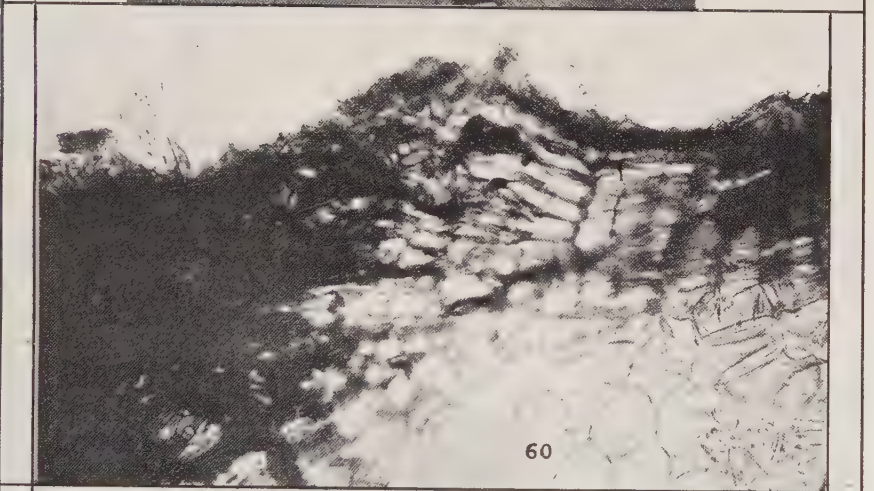
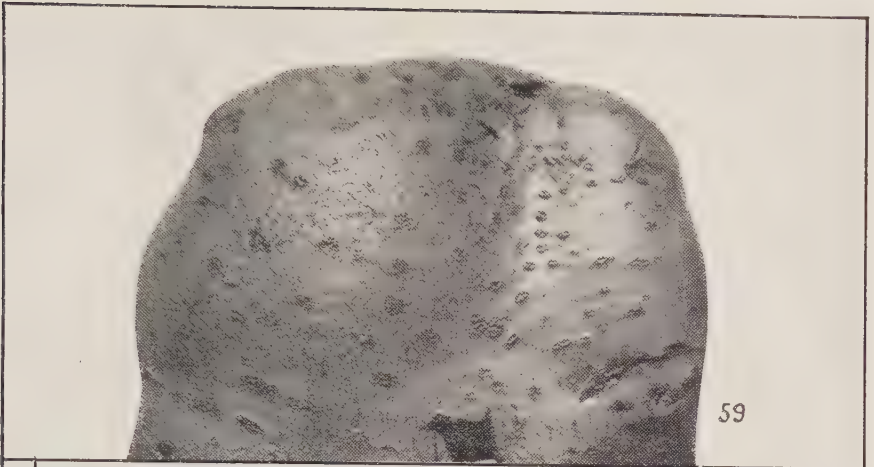


PLATE XIX.

POTATO SCAB.

**Fig.**

59. Portion of potato, showing small warty excrescences at the lenticels due to Rhizoctonia.  
60. Section of skin of same, showing filaments of Rhizoctonia penetrating the "flesh"  
of the potato .. .. . × 100  
61. Another section showing the same more clearly to the right .. .. . × 100







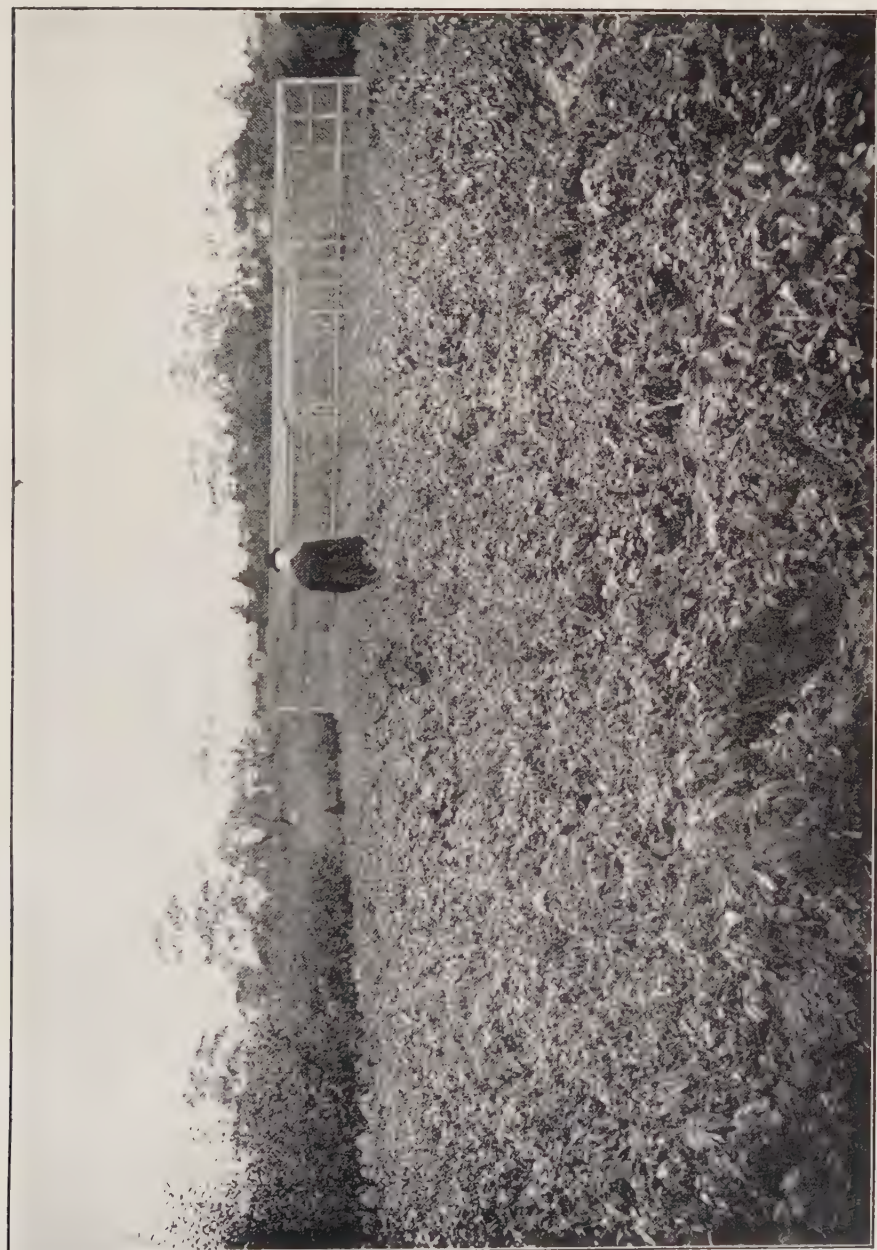


## PLATE XX.

## POTATO SCAB.

Fig.

62. View of potato plots at Burnley in connexion with Scab Experiments on 6th April, 1910, showing the luxuriant growth of the crop planted 18th December, 1909, and the bird-proof enclosure in the back ground used for experimental purposes.



C. C. Bartlebank, Phot

Fig. 62.—POTATO PLOTS AT BURNLEY, 1910







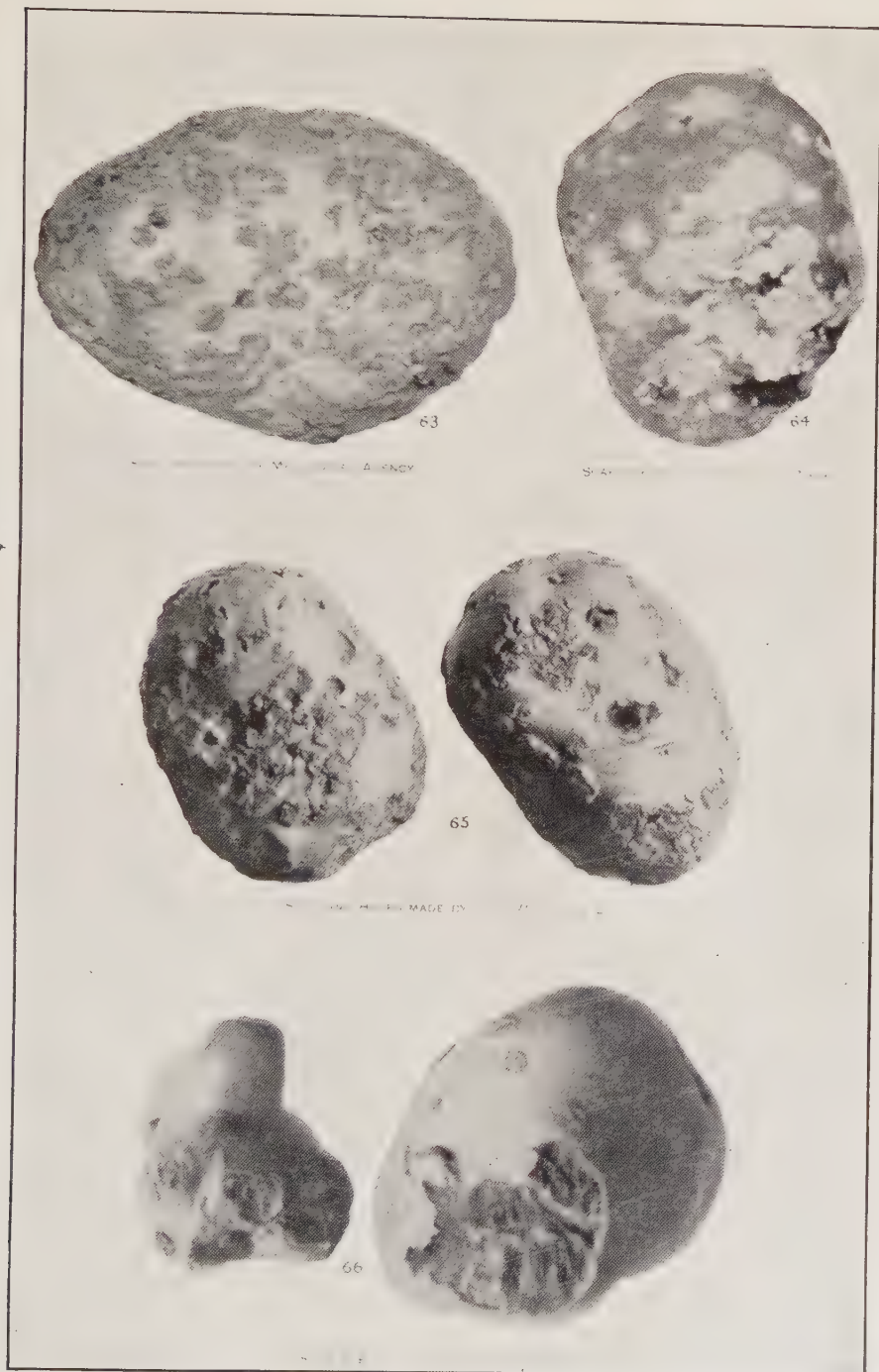
## PLATE XXI.

(From Journal of the Board of Agriculture, January, 1909.)

## POTATO SCAB.

Fig.

- 63. Scab due to mechanical injury.
- 64. Scab due to *Oospora scabies*, Thax.
- 65. Scab due to False Wireworm (*Julus pulchellus*, L.).
- 66. Scab due to *Spongospora subterranea* (Wallr.) Johnson.



SCAB VARIOUSLY PRODUCED





## PLATE XXII.

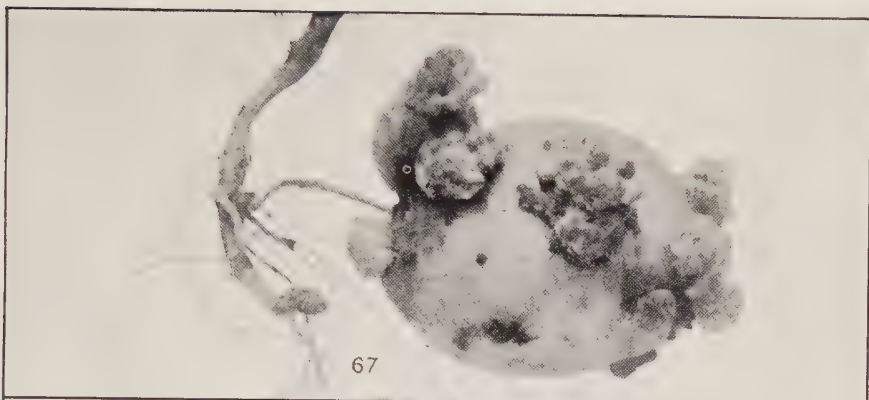
(Figs. 67, 68, after Salmon ; Fig. 69, after Clinton.)

## POTATO SCAB.

Fig.

67. Potato still attached to underground stem, showing warty excrescences of "Black Scab."
68. Growing potato plant attacked above and below ground. At  $\times$  is a diseased shoot above ground, showing the same disease.
69. Potatoes with Dry Scab or Scurf, forming slightly sunken areas of a dark-brown colour, with dot-like sclerotia or minute black specks.





SCAB ON POTATOES—BELOW AND ABOVE GROUND





## PLATE XXIII.

## DRY ROT, WHITE ROT, OR "BROWN RING."

Fig.

70. Potato showing White Rot Fungus or *Fusarium*.

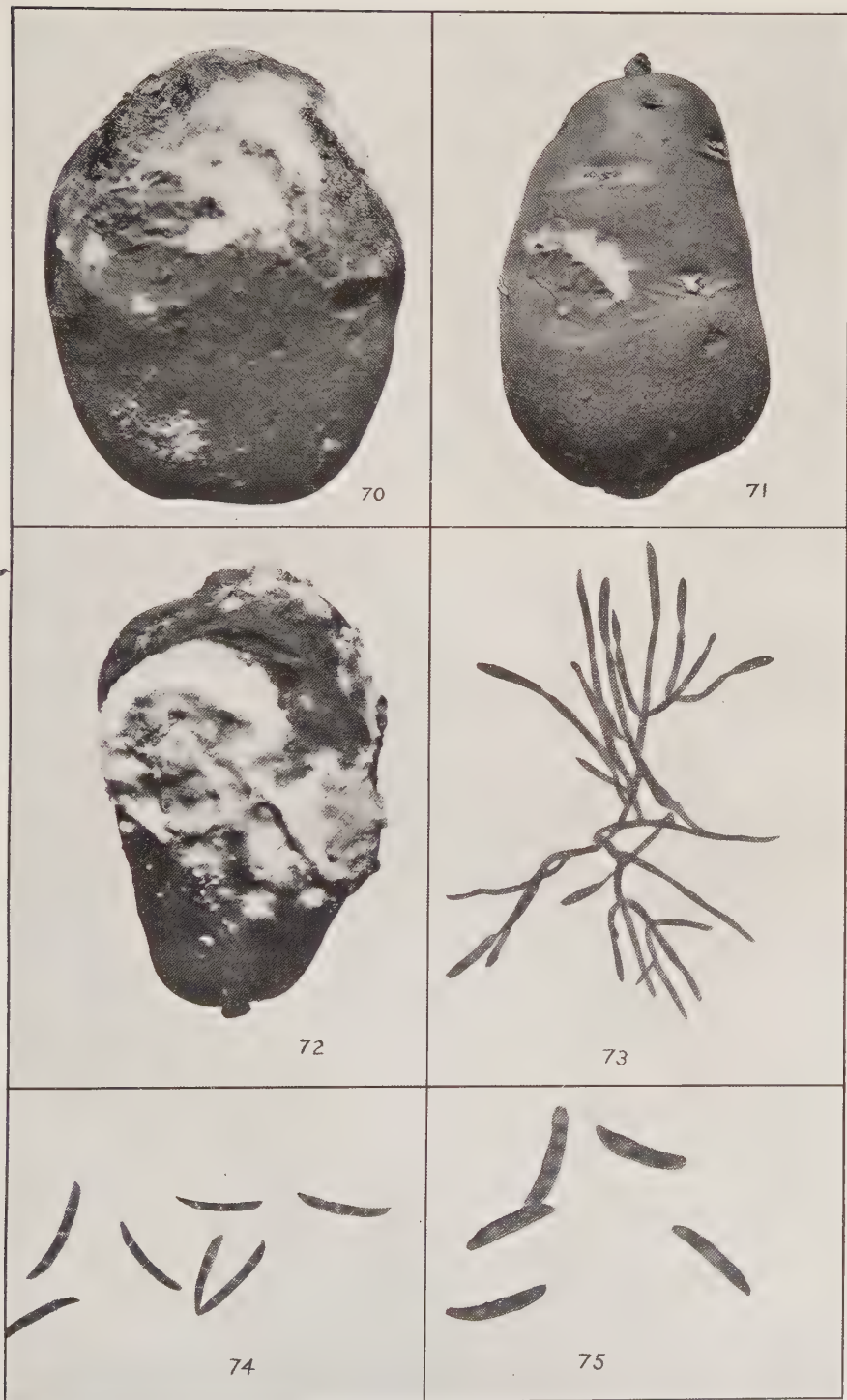
71. Healthy potato which was artificially infected at wound and fungus appeared as shown in sixteen days.

72. Advanced stage of same two months after infection.

73. Filaments of fungus with conidia attached and still immature .. .. × 500

74. Conidia detached and showing generally three cross-partitions .. .. × 500

75. Stouter conidia from potato in Fig. 72 .. .. × 500









## PLATE XXIV.

## DRY ROT, WHITE ROT, OR "BROWN RING."

Fig.

- |   |    |   |     |
|---|----|---|-----|
| 76. Conidia germinating at one end and producing slender filaments  | .. | × | 170 |
| 77. Conidia germinating at both ends .. .. .  | .. | × | 170 |
| 78. Single stout conidium germinating at both ends .. .. .  | .. | × | 500 |
| 79. Single conidium germinating at both ends, and bearing secondary conidium at end of short branch .. .. .                     | .. | × | 125 |
| 80. Conidia germinating after being kept moist for 28 hours, the germ-tubes adjoining becoming connected by cross-tubes .. .. . | .. | × | 125 |
| 81. Conidia germinating and producing clusters of conidia at end of short branches—   |    |   |     |
| A. Conidium germinating and producing on short branch a tuft of secondary conidia .. .. .                                       | .. | × | 250 |
| B. Showing larger tufts of secondary conidia .. .. .  | .. | × | 250 |
| C. Tufts of secondary conidia highly magnified and showing septate or jointed conidia .. .. .                                   | .. | × | 500 |







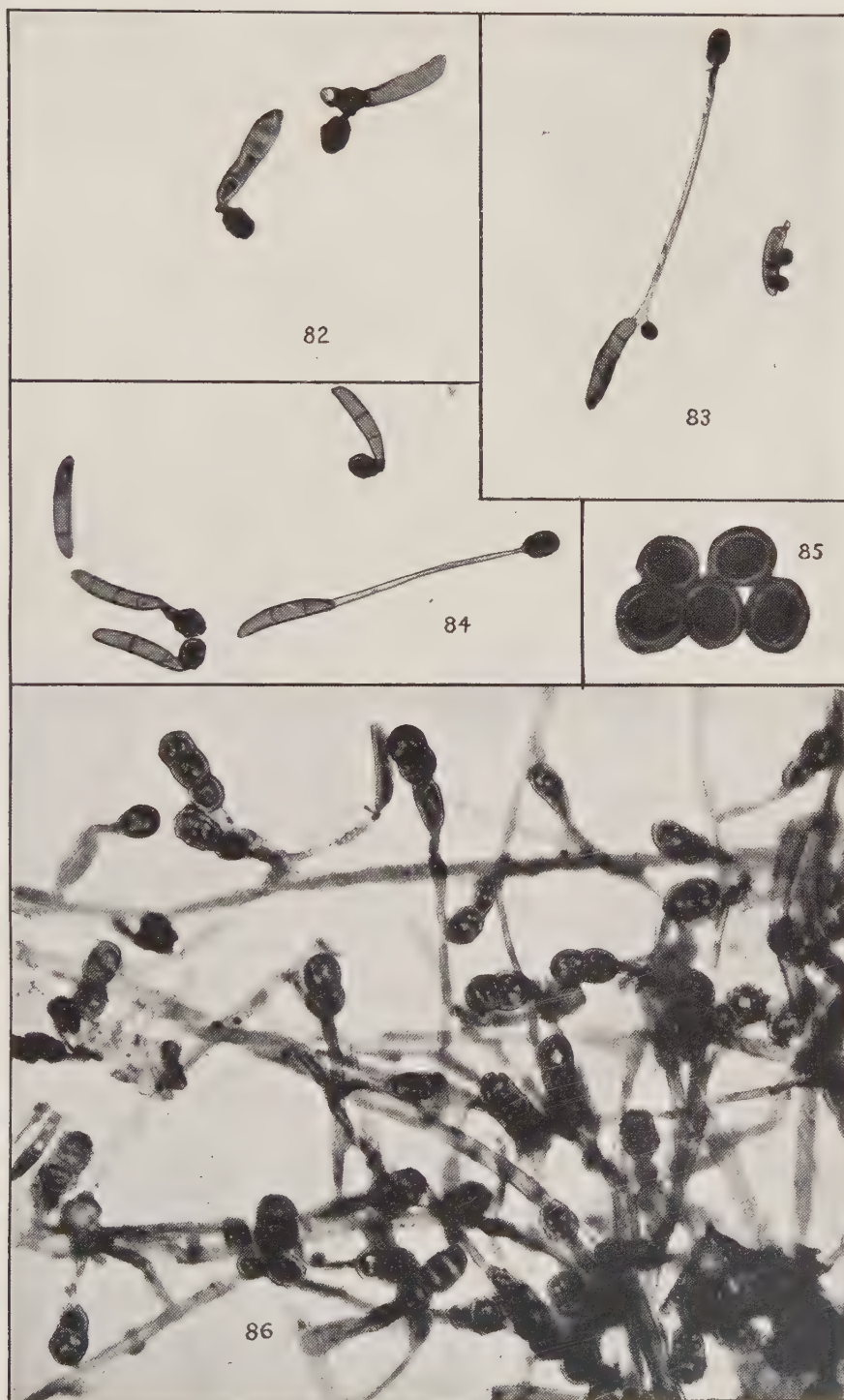


## PLATE XXV.

## DRY ROT, WHITE ROT, OR "BROWN RING."

Fig.

82. Conidia producing Resting-spores, either at the apex of a short projection from the end, or by converting one of its segments into a resting-spore which gives rise to another .. .. . × 500
83. Conidia producing Resting-spores, either directly from the segments, or from a projection at the end which is prolonged into a germ-tube and develops another spore at the apex .. .. . × 500
84. Conidia producing Resting-spores, either directly or almost directly at end, or at apex of germ-tube .. .. . × 500
85. Group of five Resting-spores, thick-walled and irregular on the surface .. × 500
86. Resting-spores produced singly at the end of filaments or in chains of two, three, or four .. .. . × 500







## PLATE XXVI.

## DRY ROT, WHITE ROT, OR "BROWN RING."

Fig.

87. Conidium at top producing elongated germ-tube, with normal Resting-spore at apex and knobs at intervals along the tube. These swellings are probably immature Resting-spores .. .. . × 170
88. Longitudinal slice of potato, showing vascular bundle ring (stained by malachite green).
89. Different slices of the one potato, showing "brown ring."
90. Healthy Tomato infected with conidia from potato and producing White Rot.









## PLATE XXVII.

## WET ROT OR BROWN ROT.

Fig.

91. Potato with "Sore eyes" or "Jammy eyes"—the early stage of the disease when the bacteria ooze out at the "eyes" and the earth adheres.
92. Section of potato, showing discoloured ring, owing to vascular bundles being filled with bacteria which ooze out in slimy dirty-white masses.
93. Potato with Brown Rot and White Rot combined.



SORE EYES AND BROWN ROT

Nat. Size







## PLATE XXVIII.

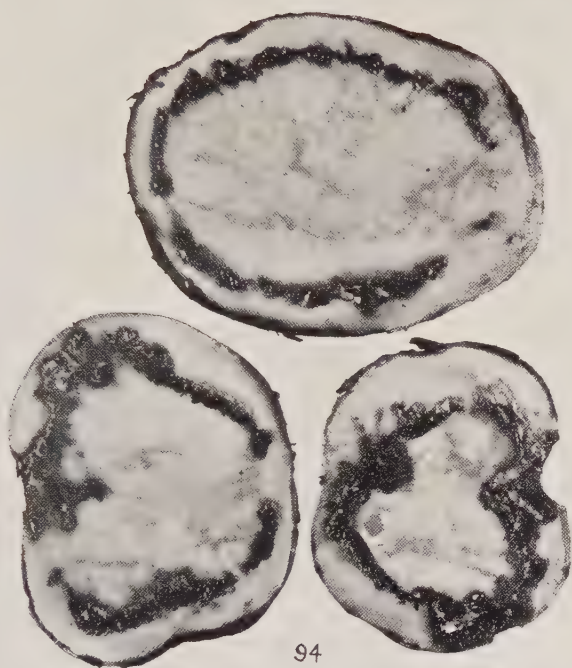
## WET ROT OR BROWN ROT.

Fig.

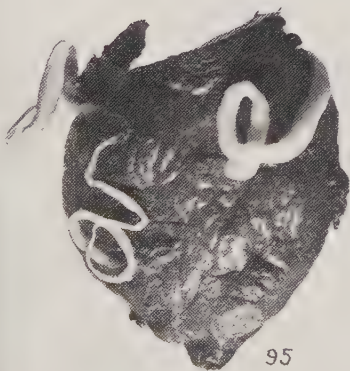
94. Section from one potato, showing Brown Rot extending from ring of vascular bundles inwards and outwards.
95. Potato preserved in spirit, showing the bacteria oozing out in dense, long, curling worm-like whitish masses. The water being withdrawn by the spirit, the vessels contracted and forced out the bacteria in solid masses.

“**THREADY EYE.**”

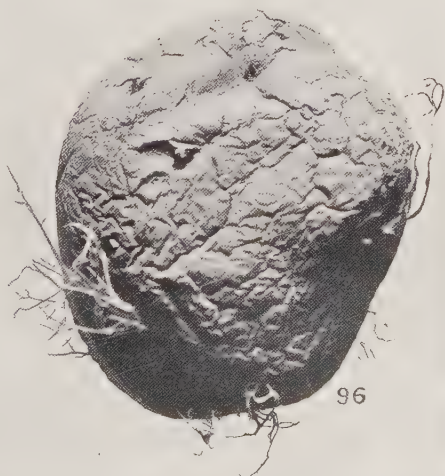
96. Potato sprouted and producing slender thread-like shoots. (This Figure is placed here for convenience and has no connexion with Wet Rot.)



94



95



96





## PLATE XXIX.

(After Dr. Erwin F. Smith.)

## WET ROT OR BROWN ROT.

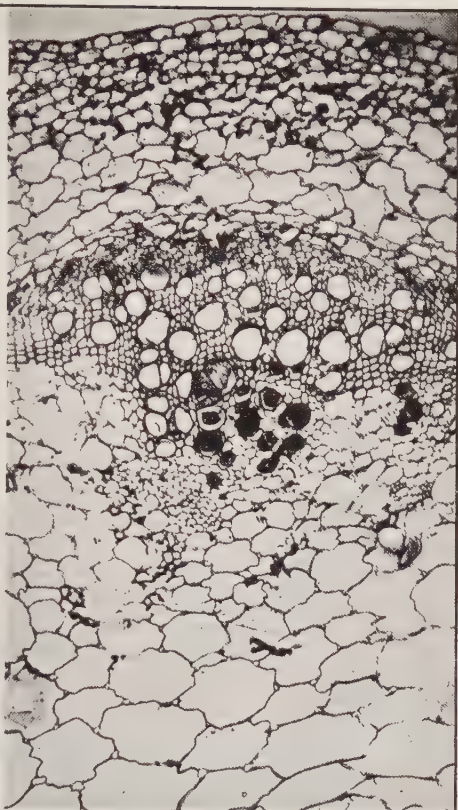
Fig.

97. Symptoms produced by infection of *Bacillus solanacearum* on stem, leaf, and tuber of potato plant—
1. Shrivelled up stem fifteen days after infection at  $\times$ .
  2. Control plant healthy.
  - 3, 4, 5, 6, 7. Tubers in various stages of infection.
  8. Section through the basal portion of an infected stem.
98. Section through the lowest portion of infected stem at point *y*. The bacteria are only seen in the vessels .. .. . Magnified
99. Small portion of preceding Figure magnified, to show how some of the vessels are crowded with bacteria .. .. .  $\times 1000$

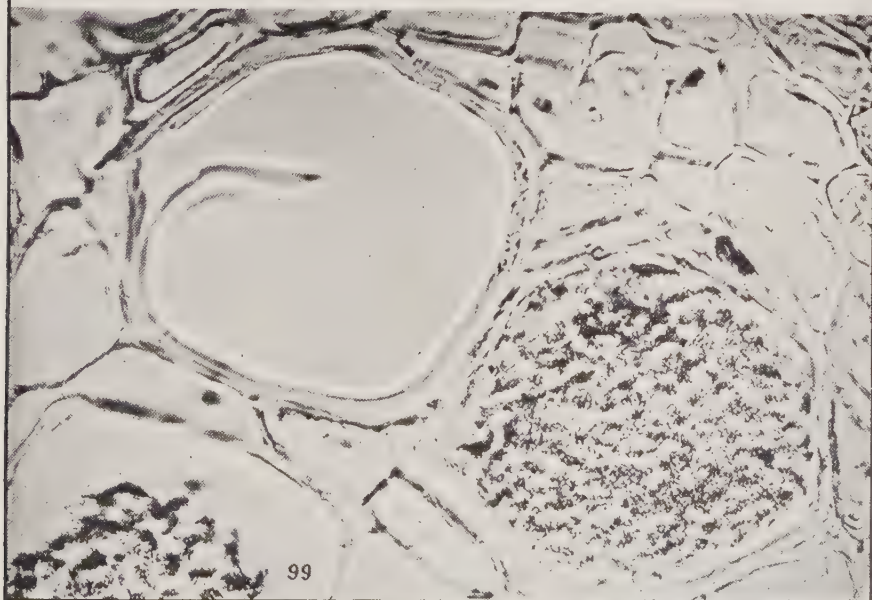




97



98



99

Reduced and Highly Mag.

INFECTION BY BROWN ROT BACILLUS



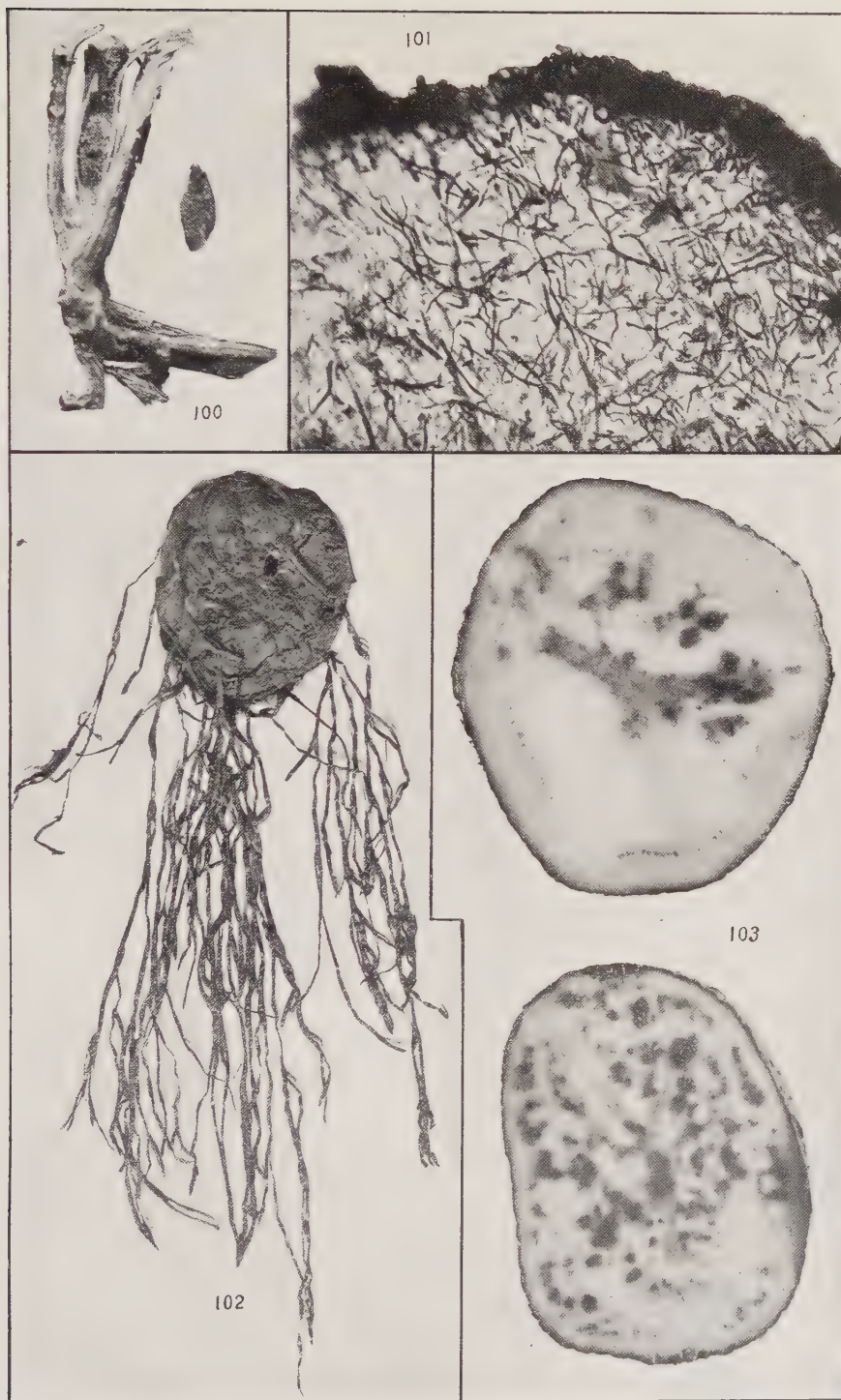


## PLATE XXX.

## SCLEROTIUM, STRINGY ROT, AND BROWN FLECK.

Fig.

100. Portion of potato stem, showing one sclerotium in cavity and the same isolated at side.
101. Section of sclerotium showing interlacing network of filaments, darker, denser, and firmer on outside .. .. . × 170
102. Potato with strands of Root Rot fungus (*Armillaria mellea*) growing over tuber and hanging down in long threads.
103. Section of potato, showing brown spots, or "Fleck," in the flesh.









## PLATE XXXI.

## BROWN FLECK AND STRINGY ROT.

Fig.

104. Cross-section of potato, showing internal brown spots.

105. Section lengthwise of young tuber with "Brown Fleck."

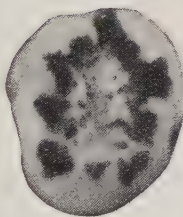
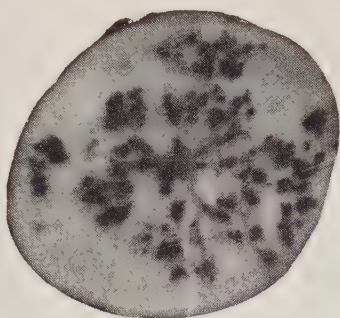
106. Surface view of tuber with network of stringy fibres of *Armillaria mellea*.

107. Section of same, showing rot extending inwardly.

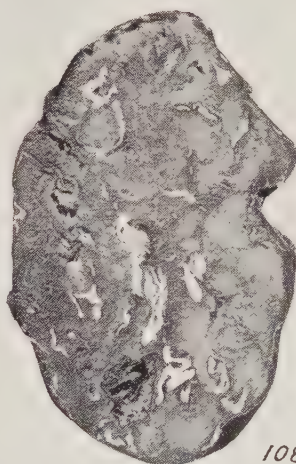
108. Section of potato, showing discoloured tissue mottled with white fungus arising from black strands on outside.



104



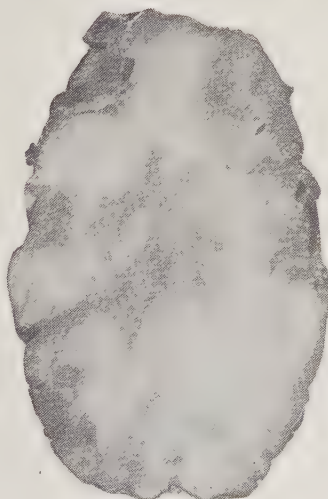
105



108



106



107





## PLATE XXXII.

## POTATO BLIGHT.

*(Continued.)*

Fig.

109. Self-sown healthy potato plant, showing the formation of tubers. The old "set" is at the base, and the underground branches are producing tubers of various sizes.

The Stem end of the potato is variously called "Navel" or "Heel."

The Crown is also called the "Rose" or terminal end.





109





## PLATE XXXIII.

## POTATO BLIGHT.

Fig.

110. Young potato-plant from Killarney with diseased tops and tubers. The leaves are all withered, the stems blackened, and the tubers all affected.
111. The "berry," "apple," or "plum" of the potato, covered with the fructification of the Blight fungus while still growing on the plant.









## PLATE XXXIV.

## POTATO BLIGHT.

Fig.

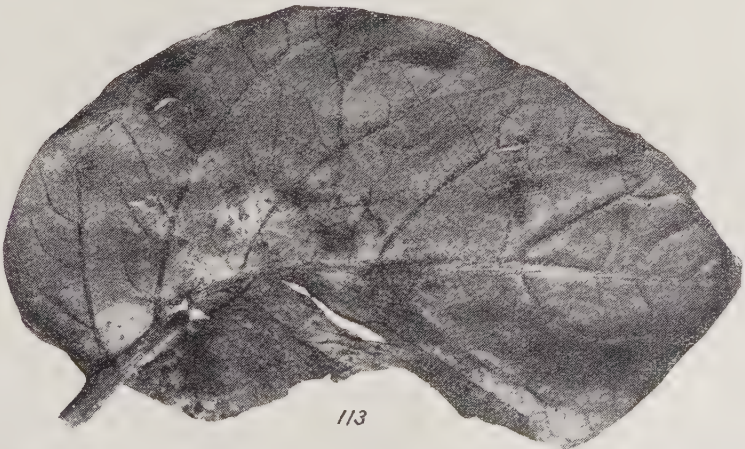
112. Under surface of diseased leaflets, showing the white mould.
113. Upper surface of leaflet, with white mould.  
Although usually developed on the under surface, it is not uncommon on the upper.
114. Small diseased potato borne above ground in the axil of a leaf.



112



114



113

C. C. Brittlebank, Phot.

Nat. Size

LEAFLETS, AND POTATO WITH IRISH BLIGHT





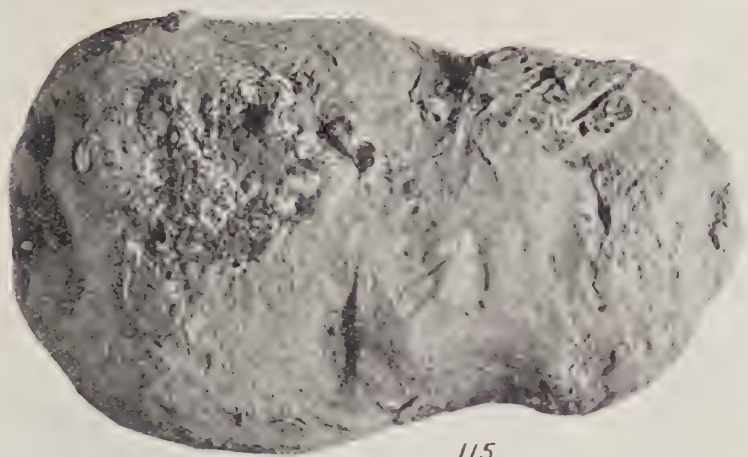
## PLATE XXXV.

## POTATO BLIGHT.

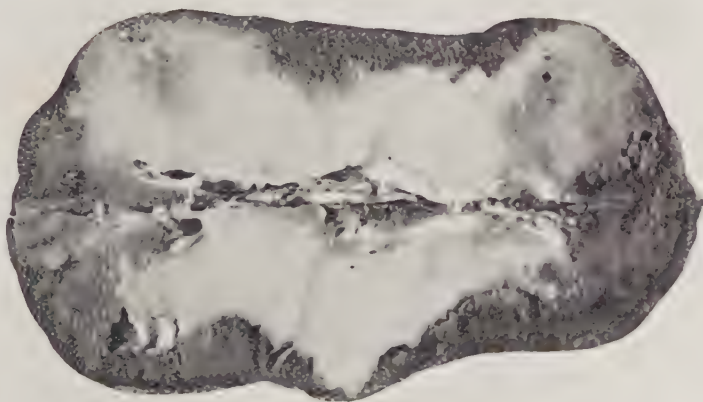
Fig.

115. Clean potato infected with sporangia beneath skin (8.7.10), showing the effect produced in 22 days—surface view and section.
116. Section of potato with disease arising from stem end and therefore probably infected from mycelium passing along underground branch.





115



116





## PLATE XXXVI.

## POTATO BLIGHT.

Fig.

117. Experimental plot planted with badly blighted potatoes, 7th November, and shown after about twelve weeks' growth.



PLATE XXXVI.

FIG. 117—"SEED" NOT HEATED.

Planted, 7/11/10. Photo, 27/1/11.





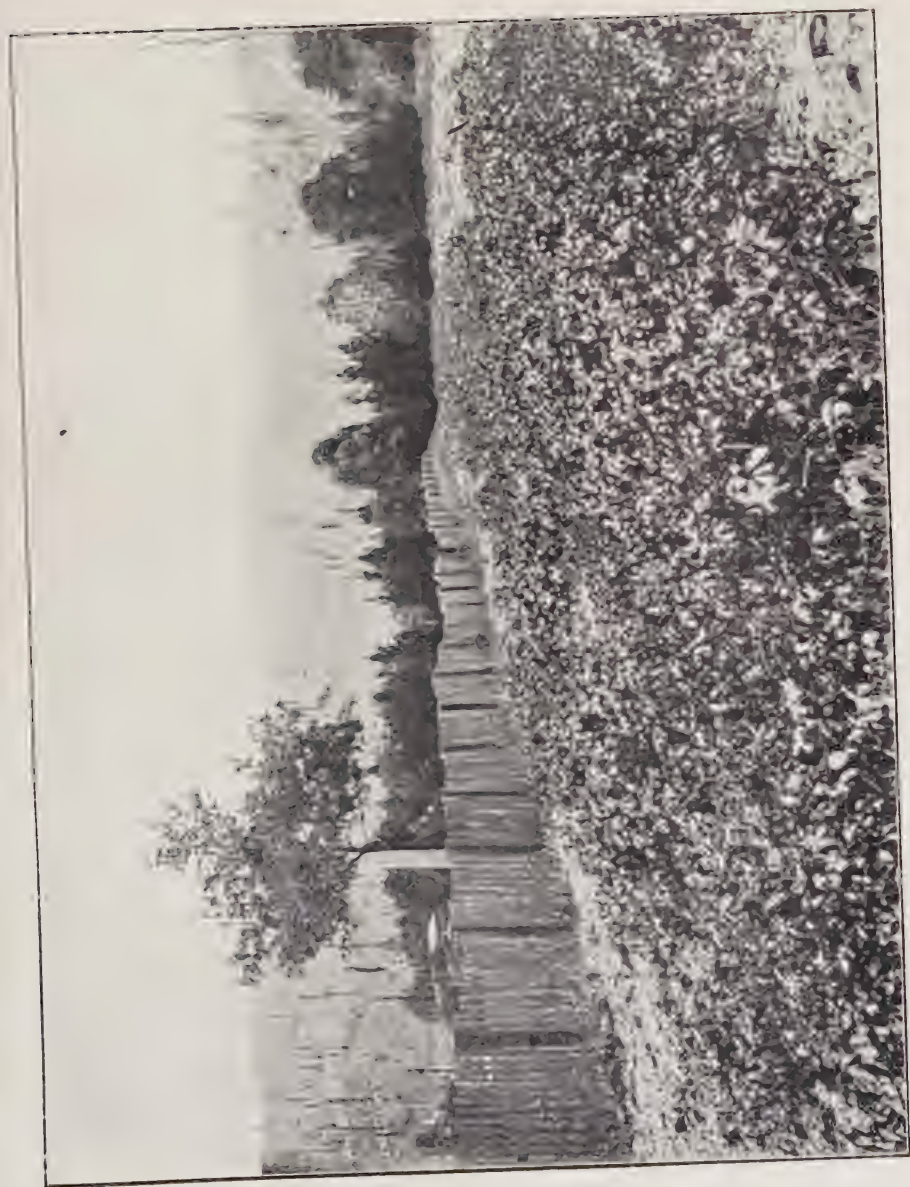


## PLATE XXXVII.

## POTATO BLIGHT.

Fig.

118. Portion of same field with diseased "sets" heated before planting.



C. C. Brittlebank, Phot.

Fig 118.—HEATED "SEED."

Planted, 7 11 10. Photo, 27 1 11.





## PLATE XXXVIII.

## POTATO BLIGHT.

Fig.

119. Young plant of Kangaroo Apple (*Solanum aviculare*) with stem and leaves showing a luxuriant growth of Irish Blight fungus.





C. C. Brittlebank, Phot.

Nat. Size

KANGAROO APPLE  
STEM AND LEAVES WITH IRISH BLIGHT





## PLATE XXXIX.

## RHIZOCTONIA ROT.

*(Continued.)*

Fig.

120. Rhizoctonia as a white fungus at "collar" extending above and below ground.
121. Rhizoctonia causing cracking and fissuring of potatoes.









## PLATE XL.

## RHIZOCTONIA ROT.

Fig.

122. "Rosette" of Potato Plant due to Rhizoctonia, showing the closely-crowded leaves and aerial tubers.



C. C. Brittlebank, Phot.

Reduced

ROSETTE OF POTATO PLANT DUE TO RHIZOCTONIA





## PLATE XII.

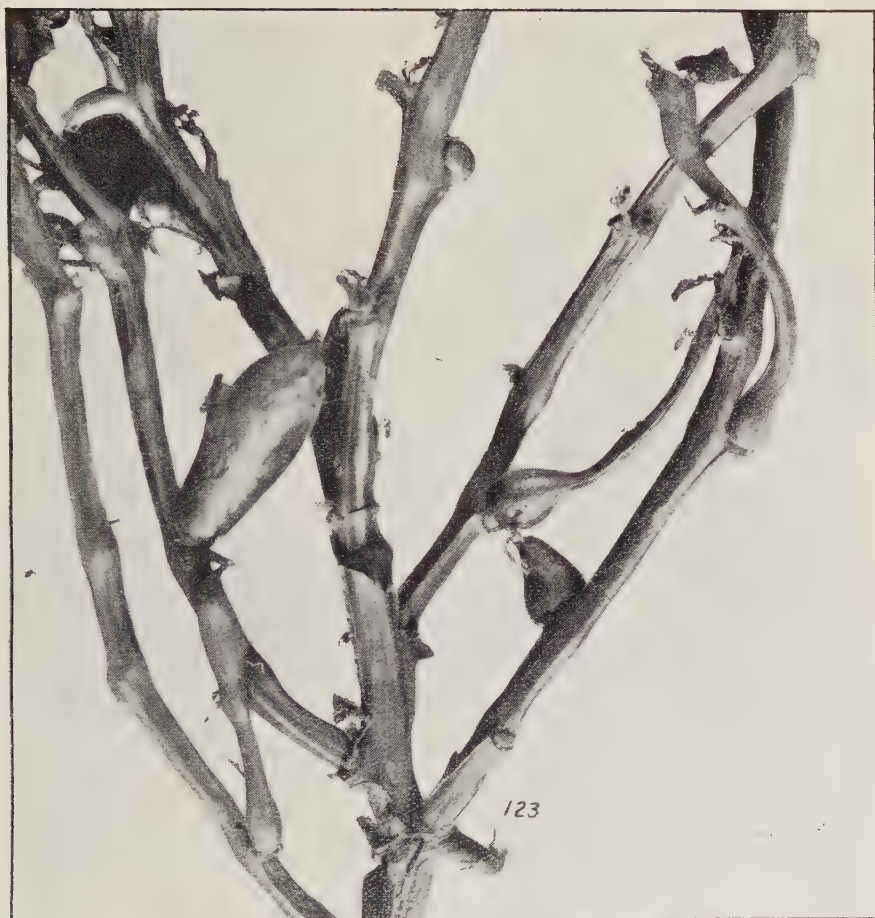
## RHIZOCTONIA ROT.

Fig.

123. Aerial tubers associated with "rosette."

124. Rhizoctonia mould at base of stem, passing on to branches and aerial tubers









## PLATE XLII.

SCAB.

*(Continued.)*

Fig.

125. Carman No. 1 with scab due to *Rhizoctonia*, grown in peaty soil.







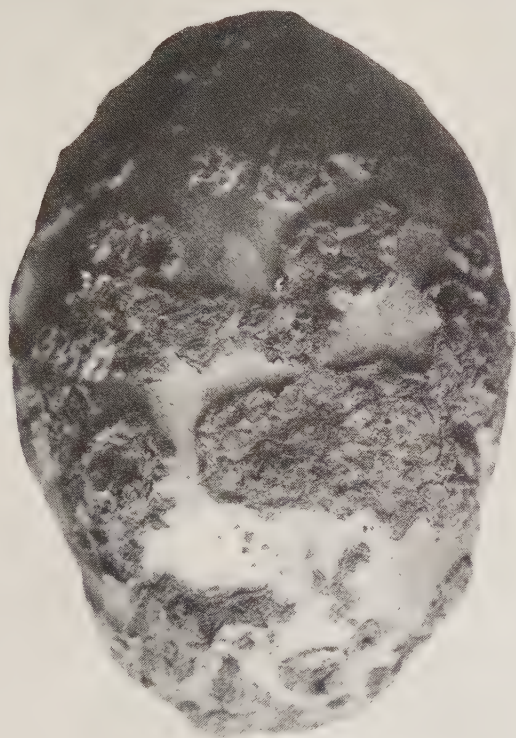


## PLATE XLIII.

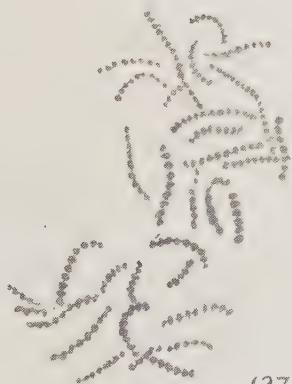
## SCAB.

Fig.

126. Carman No. 1 with *Rhizoctonia* scab.127. *Oospora scabies* which appears as a delicate whitish mould on surface of scab.



126



127





## PLATE XLIV.

SCAB.

Fig.

128. "Scab" experimental plots at Bunyip seen from South, with main crop on either side.

129. Same plots seen from North side.





J. C. Brittlebank, Phot.

SCAB EXPERIMENTS AT BUNYIP.

Planted 23/9/10. Phot. 19/12/10.





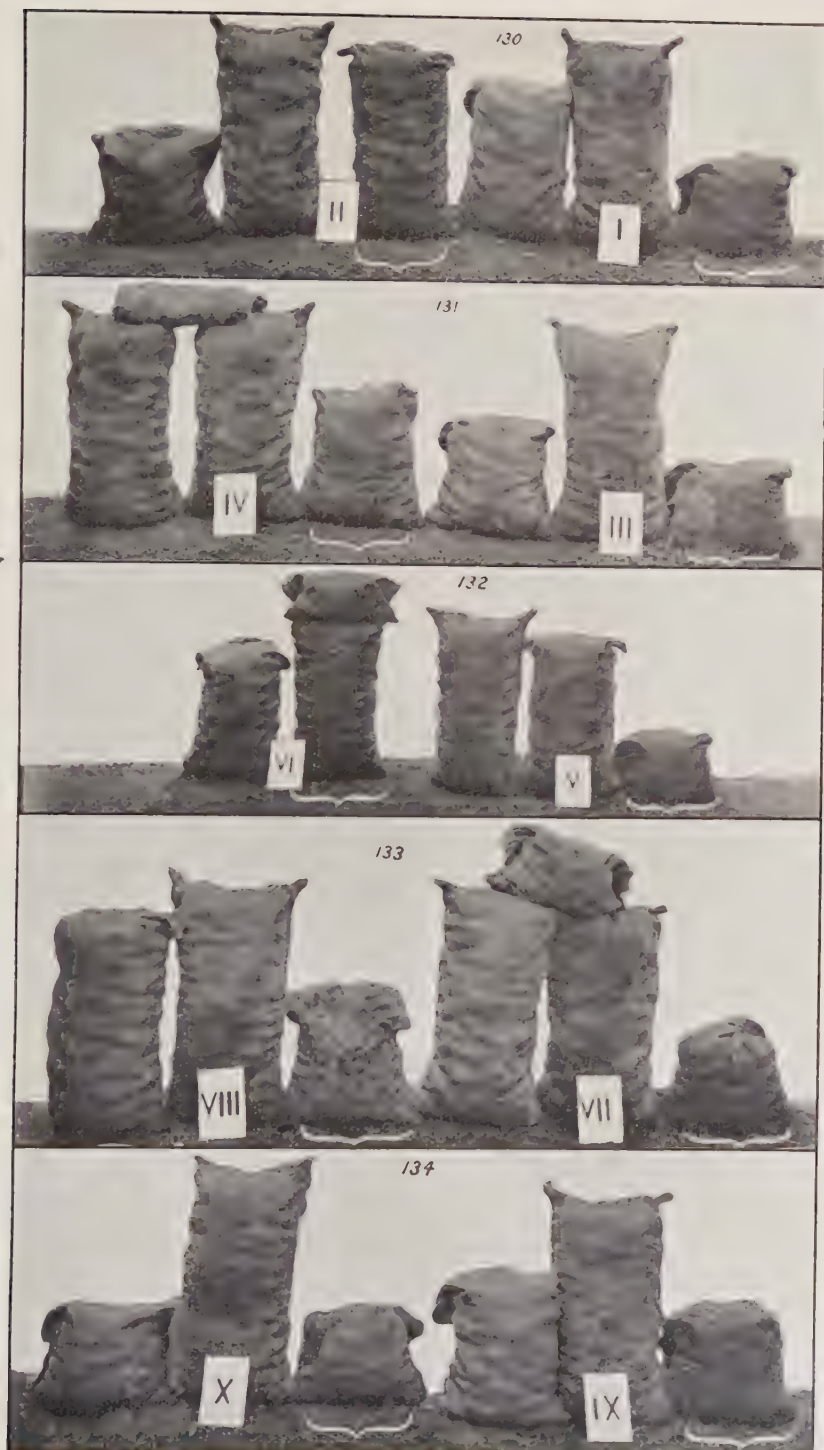
## PLATE XLV.

## SCAB.

Fig.

130. Produce of clean (I.) and scabby (II.) seed, steeped in Lime-water Bordeaux for quarter of an hour.
131. Produce of clean (III.) and scabby (IV.) seed, steeped in Formalin for two hours.
132. Produce of clean (V.) and scabby (VI.) seed, untreated.
133. Produce of clean (VII.) and scabby (VIII.) seed, steeped in Corrosive Sublimate for two hours.
134. Produce of clean (IX.) and scabby (X.) seed, steeped in Bluestone solution for quarter of an hour.

The brackets indicate smalls and scabby potatoes in each plot, and the result in the untreated scabby plot (VI.) is very marked.



C. C. Brittlebank, Phot.

PRODUCE OF TEN PLOTS, SHOWING SMALLS AND SCABBY  
POTATOES ABOVE BRACKETS







## PLATE XLVI.

## BLACKLEG.

Fig.

135. Potato plants with young leaves towards base discoloured and underground portions blackened.



C. C. Brittlebank, Phot.

Reduced

**BLACKLEG, SHOWING DISCOLORATION OF LEAVES**





## PLATE XLVII.

## BLACKLEG.

Fig.

136. Young tubers formed on plant affected with Blackleg.







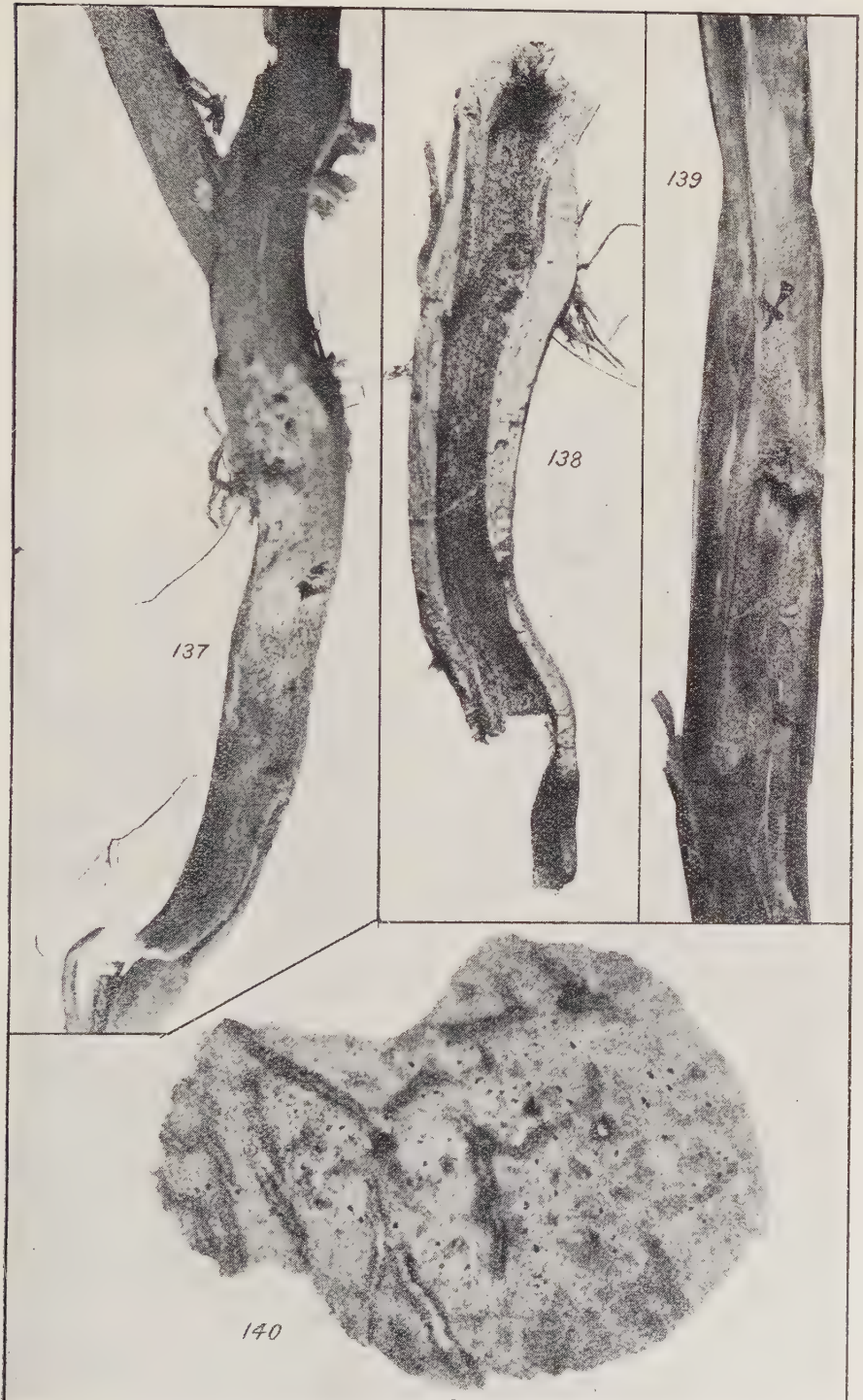


## PLATE XLVIII.

## BLACK DOT DISEASE.

Fig.

137. Blackened and brittle stem covered with sclerotia above and below ground.
138. Hollow stem opened up, showing development of sclerotia below surface of ground but not above it.
139. Portion of stem showing patches with another fungus (*Phoma*), and marked on stem with  $\times$ .
140. Skin of potato showing sclerotia scattered over it like little bits of charcoal.  $\times 3$







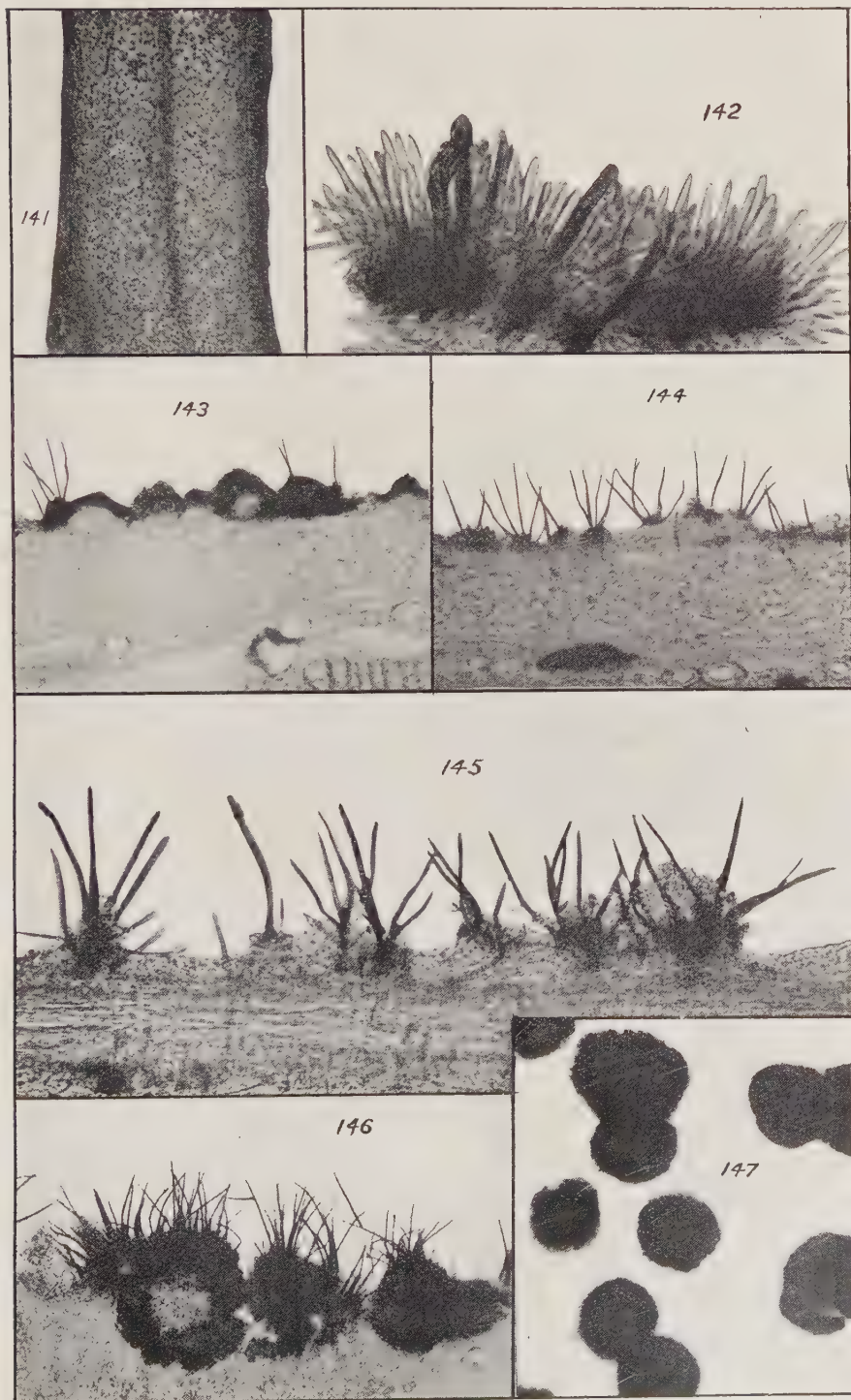


## PLATE XLIX.

## BLACK DOT DISEASE.

Fig.

- |   |         |       |
|---|---------|-------|
| 141. Surface of stem, showing black dots densely crowded together                               | ..      | × 3   |
| 142. Section showing white conidia attached to short stalks at base of rigid hairs              |         | × 250 |
| 143. Section showing sclerotia bursting through skin and some of them surmounted by rigid hairs | .. .. . | × 80  |
| 144. Section showing sclerotia surmounted by hairs and producing conidia                        | ..      | × 80  |
| 145. Sclerotia elevated above surface and immense production of conidia at base of hairs        | .. .. . | × 250 |
| 146. Advanced sclerotia in section, densely covered with hairs and with colourless contents     | .. .. . | × 250 |
| 147. Surface view of sclerotia, single or run together  | .. .. . | × 250 |







## PLATE L.

## BROWN RING, THREADY EYE, AND LENTICELS.

Fig.

148. Section of vascular bundle from "Brown Ring" showing fungus filaments in the vessels and protruding from them .. .. . × 170
149. "Thready eye" potato producing minute tubers from the "eyes" almost directly, which is a characteristic of the disease.
150. Lenticels excessively developed, showing as raised whitish spots on tubers kept under moist conditions.







## APPENDIX I.

## WEATHER CONDITIONS OVER VICTORIA FOR THE FIRST QUARTER OF 1911.

*January.*—This month was characterized by very equable temperatures over the whole State. In Melbourne the highest was 96·7, on the 5th; and the lowest, 51, on the 10th. The rains were mainly the result of the southward extension of monsoonal storms, and were almost confined to the eastern half of the State. The rainfall was generally in excess of the normal amount east from a line joining Echuca and Wilson's Promontory, and was very heavy in Gippsland, most stations there receiving more than double the average amount.

*February.*—Generally sultry and at times thundery weather continued over the whole State till the middle of the month, accompanied by phenomenally heavy rains. Between the 5th and the 8th tremendous monsoonal rains fell over the Mallee and Wimmera Districts, and during the next few days extended to the rest of the State. Owing chiefly to this great storm the rainfall over Victoria was many times more than the average amount. The rest of the month was of normal character. Shade temperatures were even more equable than in January, the highest in Melbourne being 90·3, on the 8th; the lowest, 52·4, on the 20th.

*March.*—This was another wet month. In the north the average was exceeded by about 30 per cent., but south of the Dividing Range two to three times the normal amount fell. The greatest excesses were in the Central South and in Gippsland, several stations in both areas receiving more than three times the average amount. This was almost entirely due to a slow-moving storm, which produced from the 6th to the 8th a series of most violent thunderstorms accompanied by torrents of rain, which again and again flooded the streets of Melbourne and Geelong, and did much damage to bridges and crops in Gippsland. Another general rain fell about the 18th and 19th. Rains which fell about the 13th and 14th, and from the 27th to the 30th, were confined mainly to southern areas. Temperatures were again very equable over the whole State. In Melbourne, the highest shade reading was 88·3, on the 5th; and the lowest, 49·1, on the 20th.

Although heavy monsoonal rain storms formed so marked a feature of the weather throughout the quarter, the average humidity of the air does not appear to have been above normal in Melbourne. Inland there was probably some excess and especially in the north-east.

The driest portion of the State was near the western border, Serviceton recording for the three months 285 points and Nelson 325. The heaviest rainfall was in Southern and Eastern Gippsland, Murringower, about 15 miles N.E. of Orbost, recording no less than 32½ inches, and Balook, a place 13 or 14 miles north of Alberton, 30½ inches. Other heavy totals were, in Gippsland, Genoa, 26·28 inches; Cann River, 25·87 inches; Walhalla, 23·87 inches; Gelantipy, 23·54 inches; and in the Cape Otway Ranges, Weea-proinah, 22·52 inches; and Johanna River, 22·01 inches.

The following tables show the mean temperature compared with the normal, and the humidities, at four typical stations in Victoria:—

		January.	February.	March.
Melbourne	Mean Temperature ..	67·7	68·3	64·4
	Normal Mean Temperature ..	67·5	67·2	64·7
	Humidity.. ..	59	67	69
	Normal Humidity ..	64	65	67
Colac	Mean Temperature ..	64·7	65·8	62·2
	Normal Mean Temperature ..	65·4	65·7	61·1
Mildura	Mean Temperature ..	74·8	69·9	67·6
	Normal Mean Temperature ..	77·1	77·6	70·0
	Humidity.. ..	44	58	53
Rutherglen	Mean Temperature ..	73·7	71·8	65·7
	Normal Mean Temperature ..	75·0	75·8	69·5
	Humidity.. ..	50	63	65
	Normal Humidity ..	40	42	55

## APPENDIX II.

## REGULATIONS RELATING TO POTATO DISEASES—COMMONWEALTH.

[Extract from *Commonwealth of Australia Gazette*, No. 80, dated 31st December, 1910.]

## PROCLAMATION

Commonwealth of Australia to wit.  
 DUDLEY,  
 Governor-General.

By His Excellency the Right Honorable William Humble, Earl of Dudley, a member of His Majesty's Most Honorable Privy Council, Knight Grand Cross of the Most Distinguished Order of Saint Michael and Saint George, Knight Grand Cross of the Royal Victorian Order, Governor-General and Commander in Chief of the Commonwealth of Australia.

WHEREAS by the *Quarantine Act* 1908 it is enacted that the Governor-General may, by proclamation, prohibit the importation into Australia of any animals or plants or parts of animals or plants, and that the power of prohibition shall extend to prohibition generally or with limitations as to place and subject-matter, and either absolutely or subject to any specified conditions or restrictions: And whereas by a proclamation published in the *Gazette* of 10th July, 1909, among other things the importation into Australia of potatoes from Europe, New Zealand, Norfolk Island, and from any other country was prohibited unless the Chief Quarantine Officer were satisfied that the disease caused by *Phytophthora infestans* was not existent in the country from which they were exported: And whereas it is desirable to alter the conditions under which potatoes may be imported into Australia: Now therefore I, William Humble, Earl of Dudley, the Governor-General aforesaid, acting with the advice of the Federal Executive Council, do hereby repeal paragraph (c) of Clause 9 of the said proclamation and do hereby prohibit the importation of potatoes from any country unless—

1. They are accompanied by an official certificate dated and signed by a responsible officer of a Government Department of the country of origin, identifying the potatoes, specifying the quantity, and certifying—

- (a) that they were free from the said disease at the date of the issue of the certificate;
- (b) that they were grown in the country named;
- (c) that they were grown at least 20 miles from any place known, after due investigation, to be or to have been within five years infected with the said disease;
- (d) that they were packed in the country of origin in clean new packages:

2. The bags, crates, or other packages containing the potatoes are marked on the outside with the name of the country of origin and with other distinguishing mark or marks:

3. The potatoes, after being landed, are planted in quarantine in an approved place, and, after having matured, are, with the product of their cultivation, found, on inspection, to be free from disease:

4. The importer enters into a bond in the sum of £50 conditioned that he will pay the cost of inspection of the potatoes and of supervision, that the potatoes and any parts thereof and any crop produced therefrom shall not be dug or removed from the approved place without the written permission of the Chief Quarantine Officer, and that he will give written notice of not less than one week to the Chief Quarantine Officer of his desire to dig the potatoes.

Provided that the Minister may permit potatoes which are certified by a Quarantine Officer to be free from disease to be imported under and subject to such conditions as the Minister may think fit to impose, for use as food.

Given under my hand and the Great Seal of the Commonwealth this 22nd day of December, in the year One thousand nine hundred and ten, and in the first year of His Majesty's reign.

By His Excellency's Command,

(L.S.)

FRANK G. TUDOR.

GOD SAVE THE KING.

[Extract from *Commonwealth of Australia Gazette*, No. 58, dated 29th July, 1911.]

PROCLAMATION

Commonwealth of Australia to wit.  DUDLEY, Governor-General.	By His Excellency the Right Honorable William Humble, Earl of Dudley, a Member of His Majesty's Most Honorable Privy Council, Knight Grand Cross of the Most Distinguished Order of Saint Michael and Saint George, Knight Grand Cross of the Royal Victorian Order, Governor-General and Commander-in-Chief of the Commonwealth of Australia.
---	--

WHEREAS by the *Quarantine Act* 1908 it is enacted that the Governor-General may, by proclamation, prohibit the importation into Australia of any animals or plants, or parts of animals or plants, and that the power of prohibition shall extend to prohibition generally, or with limitations as to place and subject-matter, and either absolutely or subject to any specified conditions or restrictions: And whereas by a proclamation published in the *Gazette* of 25th March, 1911, the importation of potatoes into Australia was prohibited unless certain conditions were complied with: And whereas it is desirable to amend the said proclamation: Now therefore I, William Humble, Earl of Dudley, the Governor-General aforesaid, acting with the advice of the Federal Executive Council, do hereby repeal the said Proclamation and I do hereby prohibit the importation of potatoes from any country unless—

1. They are accompanied by an official certificate, dated and signed by a responsible officer of a Government Department of the country of origin, identifying the potatoes, specifying the quantity, and certifying—

- (a) that at the date of the issue of the certificate they were, on inspection, found free from the disease caused by *Phytophthora infestans* (known as Irish Blight), and from the disease *Synchytrium endobioticum* (known as potato canker, black scab, warty disease, and cauliflower disease in potatoes);
- (b) that they were grown in the country named;
- (c) that they were grown on premises known, after due investigation, not to be or to have been during the preceding twelve months infected with either of the said diseases;
- (d) that they were packed in the country of origin in clean new packages.

2. The bags, crates, or other packages containing the potatoes are marked on the outside with the name of the country of origin and with other distinguishing mark or marks:

Provided that the Minister may permit potatoes which are certified by a Quarantine Officer to be free from disease to be imported under and subject to such conditions as the Minister may think fit to impose.

Given under my hand and the Great Seal of the Commonwealth this 20th day of July, One thousand nine hundred and eleven, and in the second year of His Majesty's reign.

By His Excellency's Command,

(L.S.)

FRANK G. TUDOR.

## APPENDIX III.

## REGULATIONS RELATING TO POTATO DISEASES.—STATE OF VICTORIA.

[Extract from the *Victoria Government Gazette* of 5th July, 1911, pp. 3455–6.]  
Vegetation Diseases Acts.

## REGULATIONS UNDER THE VEGETATION DISEASES ACTS.

*At the Executive Council Chamber, Melbourne, the thirtieth day of June, 1911.*

PRESENT :

His Excellency the Governor of Victoria.

Mr. Watt

Mr. Brown

Mr. McKenzie

Mr. Billson

Mr. Hagelthorn.

UNDER the powers in that behalf conferred by the Vegetation Diseases Acts to make regulations, among others, for the purpose of regulating the importation, introduction, or bringing into Victoria of any particular kind of tree, plant, or vegetable, likely in the opinion of the Governor in Council to spread any disease or insect, and for prescribing penalties for the breach of any regulations so made, the Governor of the State of Victoria, by and with the advice of the Executive Council, doth order as follows :—

*General.*

1. The Regulations of the 16th day of August, 1910, and published in the *Government Gazette* of the 24th day of August, 1910, shall be and the same are hereby repealed.

*Interpretation.*

2. For the purpose of these Regulations—

- (a) “Registered mark or brand” means any mark or brand registered with and approved by the Department of Agriculture of the State or territory of exportation.
- (b) “Inspector” means an inspector appointed in accordance with the provisions of the Vegetation Diseases Acts.

*Importation of Trees, Plants, and Vegetables Generally.*

3. All importers of trees, plants, or vegetables, the importation, introduction, or bringing into Victoria of which is for the time being prohibited, except subject to regulations, not being of a kind in respect to which any other specific regulation or regulations is or are for the time being in force, must give notice to the inspector under the Vegetation Diseases Act upon arrival of any trees, plants, or vegetables before the removal of such trees, plants, or vegetables from any dock, pier, wharf, station, or other place where such trees, plants, or vegetables have been landed.

4. No person shall remove any tree, plant, or vegetable landed as aforesaid unless—

- (a) the arrival of such tree, plant, or vegetable has been duly notified to the inspector, and a certificate or written authority of removal has been obtained from him ;
- (b) each case, crate, bag, bundle, or other package containing nursery stock, trees, plants, or vegetables, and each bunch of bananas has indelibly and legibly printed, marked, stencilled, or impressed upon it, or upon a label, a ticket or tag attached thereto the grower's or exporter's name and address, or his registered mark or brand, in letters or figures of not less than one-half inch in length ;
- (c) the package containing the said tree, plant, or vegetable is new.

5. All diseased trees, plants, or vegetables shall be dealt with in accordance with the Act at the expense of the importer.

*Importation of Potatoes and Tomatoes.*

6. No potatoes (*Solanum tuberosum*) or tomatoes (*Solanum lycopersicum*) shall be imported, introduced, or brought into Victoria from any other State or territory of the Commonwealth of Australia except under the following conditions :—

- (a) That the arrival of such potatoes or tomatoes has been duly notified to an inspector, and a written certificate or written authority of removal has been obtained from an inspector.



- (b) That they are accompanied by a certificate in the form in Schedule A of these Regulations.
- (c) That they are packed in new bags or other new packages, branded with the name and address of the grower.
- (d) That all such potatoes or tomatoes aforesaid are forwarded through the port of Melbourne or other places as may be approved from time to time by the Minister of Agriculture for the State of Victoria.

All such potatoes or tomatoes aforesaid imported under the conditions aforesaid shall be again inspected in Melbourne, or other approved place of entry, by an inspector of the Victorian Department of Agriculture, and if found to be free from Irish Blight (*Phytophthora infestans*) and other proclaimed diseases may be removed therefrom on payment of inspection fees as prescribed.

If, on inspection, any package is found to contain diseased potatoes or tomatoes, such package and its contents shall be refused admission into Victoria, but the contents of such package may be sorted under the supervision of an inspector under the following conditions, viz. :—

- (a) Such package, with its contents, shall be taken forthwith from the place of inspection to any place approved by the inspector ;
- (b) when sorted, potatoes or tomatoes which are found by the inspector to be free from disease shall be re-packed in new packages, and may be permitted entry ;
- (c) all potatoes or tomatoes which, after sorting, are found by the inspector to be diseased, shall, at the importer's or consignee's expense and under the supervision of an inspector, be destroyed in such manner as the inspector may direct.

#### *Importation of Slightly Diseased Fruit.*

7. Fruit which is found, on inspection, to be slightly diseased, may be imported into Victoria from any other State or territory of the Commonwealth of Australia for manufacturing purposes only by *bona fide* fruit preservers under the following conditions, viz. :—

- (a) Such fruit shall be inspected by an inspector, and may be rejected.
- (b) If passed by the inspector such fruit shall be taken forthwith to any fruit-preserving factory approved by the inspector, and there manufactured ; the refuse of all such fruit shall be absolutely destroyed in such manner as the inspector may direct. All receptacles in which such fruit has been carried shall forthwith be either destroyed by fire or otherwise treated at the factory to destroy all fruit diseases to the satisfaction of an officer of the Department of Agriculture.
- (c) No such fruit shall be sold or distributed unless in a manufactured state.

8. If, on inspection, any package is found to contain a proportion of fruit which is sound and free from disease, and also fruit which is slightly diseased, the contents of such package may be sorted under the supervision of an inspector under the following conditions :—

- (a) Such package, with its contents, may be taken forthwith from the place of inspection to any place approved by the inspector ;
- (b) when sorted, fruit which is free from disease may be re-packed in clean packages and permitted entry, and slightly-diseased fruit may be disposed of to the fruit preservers subject to all the conditions contained in Regulation 6.

All fruit which, after sorting, shall be deemed by the inspector to be unfit by reason of disease for the purpose of manufacture or sale, shall, at the importer's or consignee's expense and under the supervision of an inspector, be destroyed in such manner as the inspector may direct.

#### *Penalties.*

9. Any person who shall be guilty of a breach of or who shall fail to comply with these Regulations, shall be liable to a penalty, for the first offence not exceeding One pound, and for any subsequent offence not exceeding Ten pounds.

## SCHEDULE A.

## INSPECTOR'S CERTIFICATE.

I hereby certify that I have duly inspected the above-mentioned\*  
and have found them to be, to the best of my knowledge, clean and free from Irish Blight  
in any stage of development, and from any other\* disease proclaimed.

Dated at this day of 19  
Signature of officer of Department of Agriculture—  
Official designation—  
Address—

\* State whether potatoes or tomatoes.

And the Honorable George Graham, His Majesty's Minister of Agriculture for the  
State of Victoria, shall give the necessary directions herein accordingly.

F. W. MABBOTT.

(Clerk of the Executive Council.

[Extract from the *Victoria Government Gazette* of 5th July, 1911, pp. 3456-7.]

*Vegetation Diseases Act 1896.*

REGULATIONS AUTHORIZING AND REQUIRING INSPECTORS TO CHARGE  
FEES AND EXPENSES.

*At the Executive Council Chamber, Melbourne, this thirtieth day of June, 1911.*

PRESENT :

His Excellency the Governor of Victoria.

Mr. Watt

Mr. Brown

Mr. McKenzie

Mr. Billson

Mr. Hagelthorn.

UNDER the powers in that behalf conferred by the *Vegetation Diseases Act 1906*, to make regulations authorizing and requiring inspectors to charge fees and expenses in respect to certain matters, the Governor of the State of Victoria, by and with the advice of the Executive Council, doth order as follows :—

1. The Regulations of the 7th day of May, 1907 ; of the 10th day of September, 1907 ; of the 18th day of February, 1908 ; of the 18th day of August, 1908 ; of the 18th day of January, 1909 ; and of the 15th day of June, 1909, shall be and the same are hereby repealed.

2. The fees and expenses authorized and required to be charged by inspectors under the provisions of section 8 of the *Vegetation Diseases Act 1906* shall be as follows :—

*A.—Inspection Fees.*

For examining the understated trees, vegetables, or fruits imported, introduced, or brought into Victoria :—

Banana fruits—

For each bunch, One halfpenny.

For each case or crate, per bushel or portion thereof, One halfpenny.

Pineapples—

For each case or crate, per bushel or portion thereof, One halfpenny.

Fruit (other than bananas and pineapples)—

For each case, per bushel or portion thereof, One halfpenny.

Melons—

For each dozen or portion thereof, One penny.

Cucumbers, tomatoes, and chillies—

For each bushel or portion thereof, One halfpenny.

Cauliflowers and cabbages—

For every 5 cwt. or portion thereof (in crates or in bulk), Twopence.

Potatoes—

For every ton of 15 bags or portion thereof, Sixpence.

Vegetables (not elsewhere included)—

For every ten bags or cases or portion thereof (the total weight of ten bags or cases not to exceed one ton), Threepence.



Australian-grown peas—

For each sack or portion thereof up to 100 sacks, One halfpenny.

For every additional twenty sacks or portion thereof, Threepence.

Rice—

For every ten sacks or portion thereof, Three halfpence.

Plants, bulbs, corms, tubers, and rhizomes (not elsewhere included)—

For every  $\frac{1}{4}$  cwt. or under, Sixpence.

Over  $\frac{1}{4}$  cwt., but not exceeding 1 cwt., One shilling and sixpence.

For every additional 1 cwt. or part thereof, One shilling.

Nuts—

For every cwt. or part thereof, One penny.

Notwithstanding anything to the contrary contained in these Regulations, the minimum charge for any single inspection shall be Threepence.

#### *B.—Sorting Fees.*

For examining during the sorting of each case of fruit imported, introduced, or brought into Victoria and rejected for fruit fly or any disease:—

Threepence per case, in addition to the inspection fee.

For examining during the sorting of each cwt. or portion of each cwt. of fruits, onions, potatoes, and other vegetables contained in sacks or bags, imported, introduced, or brought into Victoria and rejected for disease:—

Ninepence per cwt. or portion thereof, in addition to the inspection fee.

#### *C.—Fees for Treatment of Trees, Plants, or Vegetables.*

For fumigating fruit:—

For each case or package not exceeding 1 Imperial bushel in capacity, One penny.

For each case or package exceeding 1 Imperial bushel in capacity, Twopence.

For fumigating or otherwise treating nursery stock, trees, plants, cuttings, or bulbs:—

For each package 1 cwt. or under, Two shillings.

For each package over 1 cwt. and not exceeding 2 cwt., Three shillings.

For each package over 2 cwt. and not exceeding 3 cwt., Four shillings.

For each package exceeding 3 cwt., Four shillings, plus One shilling for each additional cwt. or part thereof over 3 cwt.

For fumigating grain contained in packages not exceeding 1 Imperial bushel in capacity:—

For quantities not exceeding 100 packages, Threepence for every 10 packages or part thereof.

For quantities exceeding 100 packages but not exceeding 500, Twopence for every 10 packages or part thereof.

For quantities exceeding 500 packages, Three half-pence for every 10 packages or part thereof.

For fumigating grain contained in packages exceeding 1 Imperial bushel in capacity:—

For quantities not exceeding 100 packages, Sixpence for every 10 packages or part thereof.

For quantities exceeding 100 packages but not exceeding 500, Fourpence for every 10 packages or part thereof.

For quantities exceeding 500 packages, Threepence for every 10 packages or part thereof.

Notwithstanding anything to the contrary contained in these Regulations, a minimum charge of Two shillings shall be made for the fumigation of such packages.

#### *D.—Fees for Treatment of Cases and Packages.*

For dipping or treating cases or other packages containing, or intended to contain, nursery stock, trees, plants, vegetables, or fruit:—

For each case or package not exceeding 1 bushel in capacity, One halfpenny.

For each case or package exceeding 1 bushel in capacity, One penny.

For each sack or bag of any capacity, One halfpenny.

Notwithstanding anything to the contrary contained in these Regulations, a minimum charge of Two shillings and sixpence shall be made for the dipping or treatment of such sacks, bags, or other packages.

3. Such fees and expenses shall be paid to the inspector by the owner or consignee or person in possession prior to delivery of such trees, plants, vegetables, cases, or packages.

And the Honorable George Graham, His Majesty's Minister of Agriculture for the State of Victoria, shall give the necessary directions herein accordingly.

F. W. MABBOTT,  
Clerk of the Executive Council.

[Extract from the *Victoria Government Gazette* of 2nd August, 1911, pp. 3987-8.]

Vegetation Diseases Acts.

REGULATIONS UNDER THE VEGETATION DISEASES ACTS REGARDING  
THE TRANSFER OR REMOVAL WITHIN VICTORIA OF POTATOES.

*At the Executive Council Chamber, Melbourne, the twenty-eighth day of July, 1911.*

PRESENT :

His Excellency the Governor of Victoria.

Mr. Billson

Mr. Thomson

Mr. Hagelthorn.

WHEREAS the Governor in Council is empowered by the Vegetation Diseases Acts to make regulations regarding the transfer or removal within Victoria of any particular kind of tree, plant, or vegetable likely in the opinion of the Governor in Council to spread any disease or insect: And whereas the Governor in Council is of opinion that the potato is a vegetable likely to spread disease: And whereas the Governor in Council has by Proclamation in the *Government Gazette* prohibited, subject to Regulations, the bringing of potatoes into any portion of Victoria from certain other parts of Victoria specified in such Proclamation, and hereinafter (together with any further parts of Victoria which may hereafter be likewise proclaimed) referred to as "Potato Inspection Districts": Now the Governor of the State of Victoria, by and with the advice of the Executive Council, doth make the following Regulations:—

1. The Regulations made under the said Act on the 13th day of January, 1911, are hereby repealed.

*Interpretation.*

2. For the purposes of these Regulations—

"Inspector" means an inspector appointed in accordance with the provisions of the Vegetation Diseases Acts.

"Registered Mark" means any mark registered with and approved by the Department of Agriculture.

*Concerning Potato Inspection Districts.*

3. No person shall remove or cause to be removed any potatoes from any Potato Inspection District by rail or boat or otherwise unless—

(a) such potatoes shall have been, not more than four days prior to such removal, examined by the Inspector and found to the best of his knowledge and belief to be clean, free from Irish Blight (*Phytophthora infestans*), and reasonably free from other diseases of potatoes proclaimed under section 2, Act 1432;

(b) such potatoes are contained in bags, cases, or packages determined by the Inspector as sound, suitable, and clean;

(c) the bags, cases, or packages in which such potatoes are contained shall be legibly branded or stamped with the name and address (or registered mark) of the actual grower of such potatoes, and in the case of previously-used bags, cases or packages, all other names and marks (if any) shall have been effectively obliterated; and

(d) a "Transport Permit" in the form of Schedule A hereto shall have been issued in respect of such potatoes by the Inspector and to the proper railway or boat official for attachment to the waybill or bill of lading as authority for the transport of such potatoes.

*Concerning Transfers within Potato Inspection Districts.*

4. Notwithstanding anything contained in these Regulations an Inspector may examine any potatoes consigned from any place within any Potato Inspection District to any city or town situated within such district, and provided that all the conditions of these Regulations are complied with, may issue a "Removal Permit" as hereinafter provided in respect of such potatoes, without which such removal of such potatoes will constitute an offence under these Regulations.

*Concerning other than Potato Inspection Districts.*

5. In other than Potato Inspection Districts any Inspector, when authorized by the Minister of Agriculture, may examine any potatoes at any railway station, wharf, warehouse, store, market, or other place.

6. No person to whom any potatoes shall be consigned from any part of Victoria (other than a "Potato Inspection District") to any other part of Victoria within 10 miles of any place where an Inspector shall be stationed, shall remove any such potatoes from any railway station or wharf, warehouse, store, market, or other place unless—

- (a) such potatoes shall have been, not more than four days prior to such removal, examined by the Inspector, and found to the best of his knowledge and belief to be clean, free from Irish Blight (*Phytophthora infestans*), and reasonably free from other diseases of potatoes proclaimed under section 2, Act 1432 ;
- (b) such potatoes are contained in bags, cases, or packages determined by the Inspector as sound, suitable, and clean.
- (c) the bags, cases, or packages in which such potatoes are contained shall be legibly branded or stamped with the name and address (or registered mark) of the actual grower of such potatoes, and in the case of previously-used bags, cases, or packages, all other names and marks (if any) shall have been effectively obliterated ; and
- (d) a "Removal Permit" in the form of Schedule B shall have been issued in respect of such potatoes.

*Sorting.*

7. Potatoes found upon examination by an Inspector to comprise a proportion of potatoes which are diseased shall be removed by the owner or consignee or agent of either to a place approved by the Inspector, which may be the owner's store, and there sorted under his supervision, and dealt with under the following conditions, viz. :—

- (a) When sorted, all potatoes which are free from disease may be repacked in bags, cases, or packages determined as sound, suitable, and clean, by the Inspector, who may then issue for such potatoes a "Removal Permit" in the form in Schedule B.
- (b) After sorting, all diseased potatoes shall be destroyed or otherwise dealt with as the Inspector may direct.
- (c) All expenses in connexion with the supervision, handling, sorting, cartage, and destruction of such potatoes shall be paid by the owner or consignee or agent of either.

*Charges.*

8. The charge for inspection shall be Sixpence per ton or fraction of a ton, and shall be paid in respect to each lot or consignment prior to the issue of a "Transport Permit" or "Removal Permit," as the case may be ; except in cases where the owner or consignee shall have lodged a deposit in money or approved guarantee to cover all consignments to be submitted during a period of one month, when and in such cases the charge shall be calculated in respect of the aggregate tonnage of potatoes submitted for inspection during any one month until the last day of such month.

9. Any person who shall be guilty of a breach of or who shall fail to comply with these Regulations shall be liable to a penalty for the first offence not exceeding One pound, and for any subsequent offence not exceeding Ten pounds.

## SCHEDULE A.

Book No.

No.

Department of Agriculture.

Vegetation Diseases Act.

TRANSPORT PERMIT.

Victoria.

To

I hereby authorize the transport of \_\_\_\_\_ bags of potatoes grown by  
of \_\_\_\_\_ consigned to \_\_\_\_\_ at \_\_\_\_\_ from  
the \_\_\_\_\_ Potato Inspection District, on which £ : : inspection  
fees have been received.  
are due.

Inspector.

Marks

/ / 19

## SCHEDULE B.

Book No.

No.

Department of Agriculture.

Vegetation Diseases Act.

REMOVAL PERMIT.

Victoria.

To

I hereby authorize the removal from \_\_\_\_\_ of \_\_\_\_\_ bags  
 of potatoes consigned by \_\_\_\_\_ of \_\_\_\_\_ to \_\_\_\_\_  
 at \_\_\_\_\_ on which £ : : inspection fees have been received.  
 are due.

Inspector.

Marks

/ / 19

And the Honorable George Graham, His Majesty's Minister of Agriculture for the  
 State of Victoria, shall give the necessary directions herein accordingly.

F. W. MABBOTT,

Clerk of the Executive Council,

## APPENDIX A.

## EEL WORMS.

W. Laidlaw, B.Sc., *Micro-Biologist*.

The *Anguillulidæ*, to which eel-worms belong, are one of the families of the *Nematoda*, a sub-order of the *Nemathelminthes*. The *Nematoda* are a most important group of worms, for not only do we find in it those worms which attack plants, but we also find many attacking man, the domesticated and wild animals, birds, reptiles, and insects. There is scarcely any living thing which may not be attacked by them, and immense losses from death and disease are caused by their ravages. Most of the parasitic ones spend a part of their existence as free living animals; many spend their whole life in decaying vegetable matter or damp earth; while a few spend the whole of their existence in the bodies of their hosts.

## ANATOMY.

There are a great many species in the order, the determination of which is a matter of very great difficulty, for there is very little difference in their structure however much they may vary in their food and habits. None of the worms are segmented, *i.e.*, "their bodies are not divided into a number of segments which serially repeat each other, and which resemble, more or less closely, the preceding and succeeding parts." They possess a few bristles or hooklets, but have no limbs or other appendages. The body is elongated, round, and tapering at the ends. The head end is truncated, and less pointed than the tail, which is usually exceedingly slender.

All the *Nematoda* are dioecious, *i.e.*, the male and female reproductive organs are in different individuals. The young, which are usually termed larvæ, do not differ much from the adults, except in size, and the absence of sexual organs. They are usually free living.

## CIRCULATORY SYSTEM.

There is no closed vascular system, but it is probable that the clear colourless fluid contained in the cavity between the intestine and the body wall, and by which the various organs are bathed, is the blood.

## RESPIRATORY SYSTEM.

There are no lungs, and, although we know a certain amount of respiration is necessary for the life processes of the worms, we do not know how it is carried on. It may be that the lateral pores have a respiratory function.

## CILIA.

The presence or absence of cilia is a disputed point. I have not been able to make out these small processes of the cells. If none are present, it is rather remarkable, for they are universally present, from man down to the most lowly unicellular organism. "In many animals they are the sole organs of locomotion, and in almost all they perform most important functions, both in bringing food to the body and in removing waste matters from it."

## SKIN.

The skin is smooth, thick, and transparent. It lines the various apertures and tubes of the body for a greater or less distance, and consists of three layers—(1) the cuticle, (2) the subcuticle, and (3) the muscular layer. The cuticle is a secretion of the subcuticle, and lies outside it. Under the subcuticle and surrounded by it is the muscular layer.

The nature of the subcuticle is one of the debatable points in the histology of the *Nematoda*. Although nuclei are scattered through it, no cell outlines can be made out. It is a syncytium or protoplasmic mass in which the cell outlines cannot be distinguished. A close network is formed from the breaking down of the cells into fibrils which are specialized round the nerve cords. This tissue is heaped up around the dorsal, ventral, and lateral lines, and divides the enclosed muscle cells into four quadrants. In the dorsal and ventral thickenings are specialized nerve cords, and, in the lateral thickenings, lie the excretory canals.

## NERVOUS SYSTEM.

According to Jammes, the nerve tissue is of the same nature as the subcuticular tissue, only more differentiated, or, rather, it has retained more of the cellular character of embryonic tissue.

The central organ of the nervous system is the circumoesophageal ring which surrounds the pharynx close to the anterior end of the body. There are a few ganglion cells in the ring aggregated round the points of origin of the nerves. Nerves run forward towards the mouth, and, running backwards, there are six main trunks, the dorsal and ventral being the largest. As before stated, these run in the median, dorsal, and ventral



thickenings of the subcuticular tissue, and are connected, one with another, by fine lateral branches running through the subcuticle. So far as I know, there is nothing peculiar in the histology of the nervous system.

#### MUSCULAR SYSTEM.

If we make a transverse section of a nematode, we will see numerous muscle cells lining the subcuticle, except where the dorsal, ventral, and lateral thickenings are. The muscle cells are spindle shaped and of considerable size. There is a contractile portion next to the subcuticle, consisting of a number of columns in two regular rows. The medullary half which projects into the body cavity consists of a fibrillar spongioplasm filled with a clear hyaloplasm without structure. The medullary portion contains the nucleus.

The fibrils of the spongioplasm fill up the spaces between the contractile columns and are continuous with the fibrils of the subcuticle. Special muscles are found at the different orifices of the body.

#### BODY CAVITY.

As mentioned previously, the skin contains, in its thickness, the muscular, nervous and excretory systems, and within it lies the body cavity, in which we find the digestive and reproductive systems. There are no mesenteries dividing the body cavity into compartments. It contains a colourless coagulable fluid with many corpuscles, which probably act as carriers of oxygen, though nematodes seem to require very little of that gas, their life processes being slow. Bunge found that certain parasitic species lived from four to six days in a fluid free from oxygen.

#### DIGESTIVE SYSTEM.

The mouth is anterior and terminal, and leads into an alimentary canal which runs straight through the body to the anus, which is situated on the ventral side of the body and is not terminal. This simple tube may be divided into three main parts—the œsophagus, the intestine, and the rectum. The œsophagus extends from the mouth to the intestine. It is triangular in section, lined with cuticle continuous with the skin covering the body, and, like it, is shed at the various moults. Its walls are thick and muscular, and it has as its posterior end a bulbous swelling adapted for a special purpose. It is armed with a spear in the species under consideration. The spear is used to pierce the tissues of the plant upon which the animal lives. A small gland, supposed to be salivary, lies in the thick wall of the œsophagus, and opens into its lumen by a fine tube.

The intestine, into which the œsophagus opens posteriorly, is a simple tube, made up of a single layer of nucleated columnar cells. The internal wall has a coat of a chitinous nature which has many minute pores. The rectum is short, and its cuticular lining, like that of the œsophagus, is cast at intervals. The rectum possesses a sphincter.

#### EXCRETORY SYSTEM.

The excretory system consists of two canals embedded in the lateral thickenings of the subcuticular tissue. They end blindly behind, but anteriorly they bend downwards and open by a common pore on the ventral surface near the head. They contain a fluid, but nothing is known of its composition. Cobb supposes it to be urinary in its nature.

#### REPRODUCTIVE ORGANS.

The sexes are distinct, the males being smaller than the females. The genital opening in the female is ventral and near the middle of the body; while, in the male, the anus serves for the genital opening as well as for getting rid of the excrement. The male has a genital bursa and one or more spicules at or near the cloaca.

The internal organs in the male consist usually of a single tube, which we may divide into a testis, a vas deferens, a vesicula seminalis, and an ejaculatory duct.

In the testis the protoplasmic granules enlarge and become elongated cells (mother cells), which group themselves about longitudinal axes or rachises. There may be as many as ten of these axes. As these mother cells mature they become detached from each other, and so give rise to the spermatozoa. The spermatozoon of a nematode has no flagellum; and, though it cannot move actively, it has a well-defined amoeboid movement. The spermatozoa do not become mature till they reach the uterus of the female.

The internal reproductive organs of the female are double, and consist of ovaries, oviducts, and uteri. The vagina is single, and is lined by a continuation of the cuticle covering the body. The ova arise from the germinal epithelium at the blind ends of the ovaries, and, as they get pushed forwards into the tubular part, they enlarge and arrange themselves around a central axis or rachis, which seems to be formed by the coalescing of the ends of the cells. In the small free living forms there is no rachis. The ovum has a cell-wall enclosing a reticulated protoplasm with nucleus and one or more nucleoli. After copulation, the spermatozoa collect in the ovary close to the uterus, and here the ovum is fertilized. After fertilization, the egg acquires a shell which is

probably deposited around it from the semi-fluid contents of the uterus. The shell is chitinous and very resistant to chemicals. Drying or soaking in water has no effect on it. In some species it is provided with a process which enables the embryo to escape one end coming off like a little lid or cap.

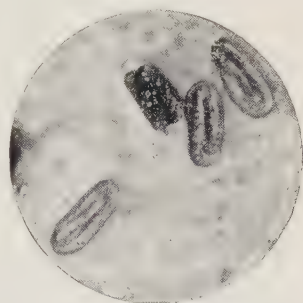
The eggs differ greatly in their rate of development, karyokinesis going on much more rapidly in some than in others. This is probably, in a great measure, due to the artificial conditions under which the observations are made. Eggs that have been dried for months and then moistened, hatch out, the embryos showing movement within the egg in less than two days. Each female worm produces from 250 to 300 eggs. As the life cycle is complete in three weeks or so, and, as there are ten or more generations in the year, it is not difficult to understand the spread of the pest.

The foregoing description of the *Nematoda* applies also to the genera which attack plants, viz., *Tylenchus*, *Aphelenchus*, and *Heterodera*.

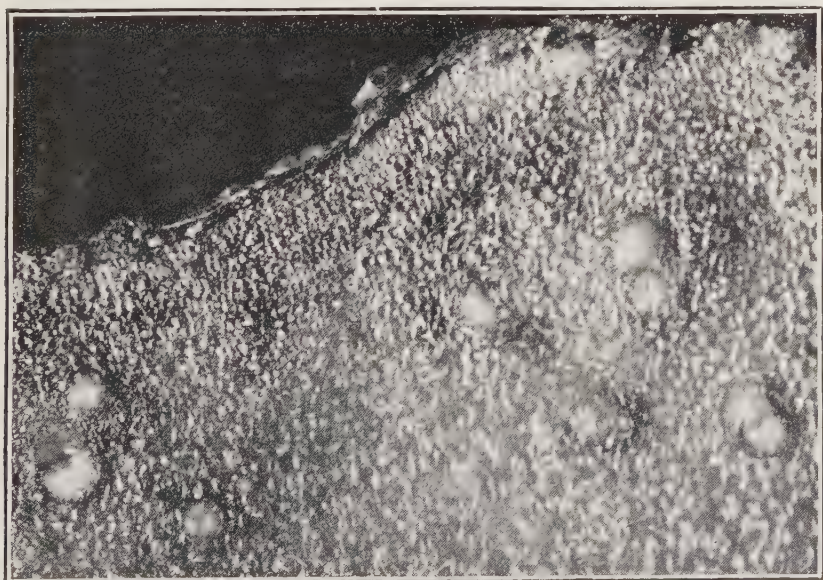
*Heterodera radiculicola*, the potato eel-worm, is about one-twenty-fifth of an inch in length, being just visible to the naked eye. It causes swellings or blisters on the tubers, which often break down, causing scablike blemishes on the skin.

#### CYSTS.

If we take a potato showing these swellings or blisters, and cut it at right angles to the surface, we will find, under the skin, at depths varying from  $\frac{1}{32}$  to  $\frac{1}{2}$  of an inch, little rounded cysts which are quite visible to the naked eye, being about the size of a pin-head. These are the female worms which have become distended with eggs. In a potato that is newly dug, the little cysts are transparent and very difficult to make out with the naked eye; but, in one that has been kept for some time, they are easily seen as the cyst becomes opaque and pearly-white in appearance, and by-and-by some of



1. EGGS.



2. CYSTS.

the starch cells in the neighbourhood become brownish through degeneration. In a potato that has been dug for some time the cysts are easily removed for the purpose of observation, the wall of the cyst, which is really the epidermis of the worm, having become tougher with age. If we place an individual cyst in water it swells up by osmosis, and usually a portion of the contents is expressed. From the contained eggs, living worms are hatched out in eight days. This, no doubt, is slower than it will be in natural conditions, owing to the difficulty of keeping the eggs with just the requisite amount of moisture.



## LIFE HISTORY.

The usual life cycle of the potato worm is quite simple. When a potato with blister, *i.e.*, with the female in the cystic form, is planted, the embryo worms are set free in the decaying set, through the rupturing of the body of the adult. These find their way into the soil, where they live till they are sexually mature. Conjunction of the sexes takes place, and the females bore their way into the young potatoes of the new crop there to encyst themselves again.



3. FEMALE WORM.

The accompanying micro-photograph shows the female at the commencement of the cystic stage.

It must be borne in mind that this worm can pass through its whole life cycle without becoming encysted in a tuber, as it is able to live in the decaying vegetable matter in the soil. In this case the female does not become distended with eggs, fewer being produced.

To obtain a pure culture of the potato worms, an infected potato was washed and placed in sterilized soil. After a time the worms were collected from the soil and decaying set, care having been taken during the period of growth to water with nematode-free water. By feeding the worms on small pieces of boiled potato and onion, I was able to keep them alive and healthy. They went through their whole life cycle in the free state, and slowly increased in numbers. The females did not become

"citron shaped," and were quite as active as the males. No non-motile larvæ were observed.

The damage to a crop is mainly caused by the females, sexually mature males being seldom found in the tissues of a potato.

When a culture of potato worms is kept for some time, little white dots, the size of a small pin's head, will be found on the sides of the dish, quite away from the food and moisture. On removing one of these small clumps to a microscopic slide and moistening it with water, it will be found to consist of a mass of worms of all sizes, except the smallest larvæ, though there are, as a rule, very few sexually mature adults.

I allowed one of these dishes to dry up completely, and kept it so for over twelve months. At the end of that time I took one of the little dried-up clumps and placed it on a slide with some water, and, in a few hours, the worms were moving about in a lively manner. This gathering into clumps may be adopted by the worms as a means of preservation, for it is generally seen when the food supplies or the moisture in the dishes are becoming low. Or this massing together may be a means of enabling a colony of young and vigorous worms to be transported more readily from place to place by the agency of animals, birds, insects, &c.

## CHANGES IN THE FOOD SUPPLY.

All the groups are, to a certain extent, restricted in their choice of food. When their natural nutriment is withheld and something else substituted, they become sluggish, reproduction ceases, and many of the worms die before they are able to adapt themselves to the change. These facts point strongly to the advantages to be gained by rotation of crops.

## SAPROPHYTIC WORMS.

Minute nematodes abound in moist soil, around the roots of plants, and in decaying vegetable matter. They are not directly parasitic in plants, and, so far as is known, do no harm. As many as six different genera have been found in the blemishes on the skin of a damaged potato, and, in some cases, not a single one of them belonged to the family *Heterodera*.

I have never succeeded in keeping worms alive for longer than three or four days that did not belong to the families *Tylenchus*, *Aphelenchus*, or *Heterodera*; and this, with the anatomic differences, to my mind, proves that many of the worms regarded as injurious are merely saprophytic.

In soil sterilized by steam for two hours I planted very scabby potatoes containing nematodes in the blemishes on the skin, but no cysts. Previous to planting, the tubers with the exception of the control, were steeped in 1-300 formalin. When dug, the tubers

showed no trace of "scab." All of those from the unsteeped "set" showed more or less scab. The same procedure was carried out with potatoes having eel-worm cysts; and, in every case, steeped and unsteeped, eel-worm was found in the young crop.

Scientists do not agree in their statements with regard to eel-worm, one remarking that "Though eel-worms are almost universally considered as doing great injury to cultivated plants, and in all probability such is the case, yet I have often wondered whether they are always the primary cause of mischief. Experience has taught me to always look for fungus mycelium when I cut an eel-worm gall, and I am rarely disappointed"; while another says that "The fungus is always secondary, the primary damage being caused by the eel-worm."

For my own part, I consider both are right and both wrong; for I have examined many plants where the primary, and, indeed, the only affection was due to the eel worm, and I have examined quite as many where the eel worms found were mere saprophytes living in the decaying tissues of the plant, the primary damage having been caused by some other agency.

#### TREATMENT.

Various remedies have been tried, such as saturating the soil with carbolic 1 in 20; gas lime spread on the soil and intimately mixed with it; mixing naphthaline with the soil; and sulphate of potash, 4 cwt. to the acre. I have had good results with both carbolic acid and naphthaline, but they are too expensive to use over large areas.

Experiments are at present being carried on by this Department for the eradication of the pest; and, though they appear very successful, it is too early in the season to speak positively.

In using any insecticide, it must be applied three times, a fortnight intervening between each application; the reason for this is that the eggs hatch out in from eight to ten days in favorable circumstances. The first application kills off the adult worms, and the succeeding ones kill the worms hatched out from the eggs already in the soil.

A dressing of peaty soil was tried on onion eel-worm infested soil at Portarlington, with no result.

Steeping seed potatoes in formalin or corrosive sublimate is of no avail. The chemicals do not penetrate deeply enough to reach the cysts, and, did it reach them, it would not kill the eggs, the envelopes being very resistant to all kinds of chemicals.

Growing the same crop year after year on the same ground is the greatest cause of the soil becoming infested with eel-worm. They can live on a great many plants cultivated and uncultivated, but they can only change from one kind of plant food to another with difficulty. Hence, when rotation of crops is practised, the worms never become a serious menace to the farmer.

In selecting seed for planting, the grower must see that it is free from "blisters" or galls, rejecting all that are in the least suspicious, for, unless a potato is badly affected, the infection is not easily seen.

#### ILLUSTRATIONS.

1. EGGS OF POTATO EEL-WORM  $\times 120$ .
2. SECTION OF POTATO SHOWING CYSTS  $\times 10$ .
3. FEMALE WORM AT THE COMMENCEMENT OF THE CYSTIC STAGE  $\times 160$ .

## APPENDIX B.

## INSECT PESTS OF THE POTATO.

C. French, Jr., Acting Government Entomologist.

## INTRODUCTION.

Many of the insect pests of the potato known to science are found in Victoria, though, fortunately, we have not the dreaded Colorado beetle and some others which are prevalent in America and elsewhere. With the careful inspection and quarantine in Melbourne of all potatoes arriving from abroad, growers have now less fear of new pests being introduced. Should any such appear it would be advisable to at once send specimens to the Department of Agriculture, in order that action may be taken for their suppression.

Many native insects whose natural food is being destroyed as new land is brought under cultivation are turning their attention to the potato and other crops, so growers should always be on the alert. With the modern outfits, the spraying of crops is now an easy matter, and most of the chemicals used are obtainable at a reasonable price.

Most of the insects described in the following pages are known to growers, and on this account their technical descriptions have been curtailed.

## THE POTATO THRIP.

(Thrips tabaci, Lindemann.)

During the last few years these destructive little insects (probably introduced from Europe) have caused growers considerable losses, and they are unfortunately on the increase. They attack plants of all kinds.

If *débris* in sheltered places is examined during the winter months, the thrips will occasionally be found in great numbers. They are very slow in their movements, and a severe winter is the means of lessening their numbers considerably as they cannot stand cold wet weather.

Where they have survived the winter the first warm day in October brings them out. They then appear in millions as if by magic. If the potato leaves are examined underneath, the thrips will be found in all stages of development. The lower leaves of the plant are generally attacked first, and, as these are destroyed, the top ones are affected in turn. In a short time the whole plant shrivels up, and the potatoes are often only the size of marbles.

In Victoria the life cycle of these insects is as follows:—Development of egg, 3 to 4 days; development of larva, 7 to 10 days; development of nymph, 4 days; total development, 10 to 15 days. In other countries they have taken as long as 47 days to develop. Should the weather be warm, the eggs will of course develop more quickly than in cold weather. They are deposited in slits or other well concealed positions on the stems and foliage.

## PREVENTION AND REMEDIES.

The thrip pest is indeed a serious one, and growers will sooner or later be compelled to take united action against it, otherwise it will be almost impossible to grow good crops.

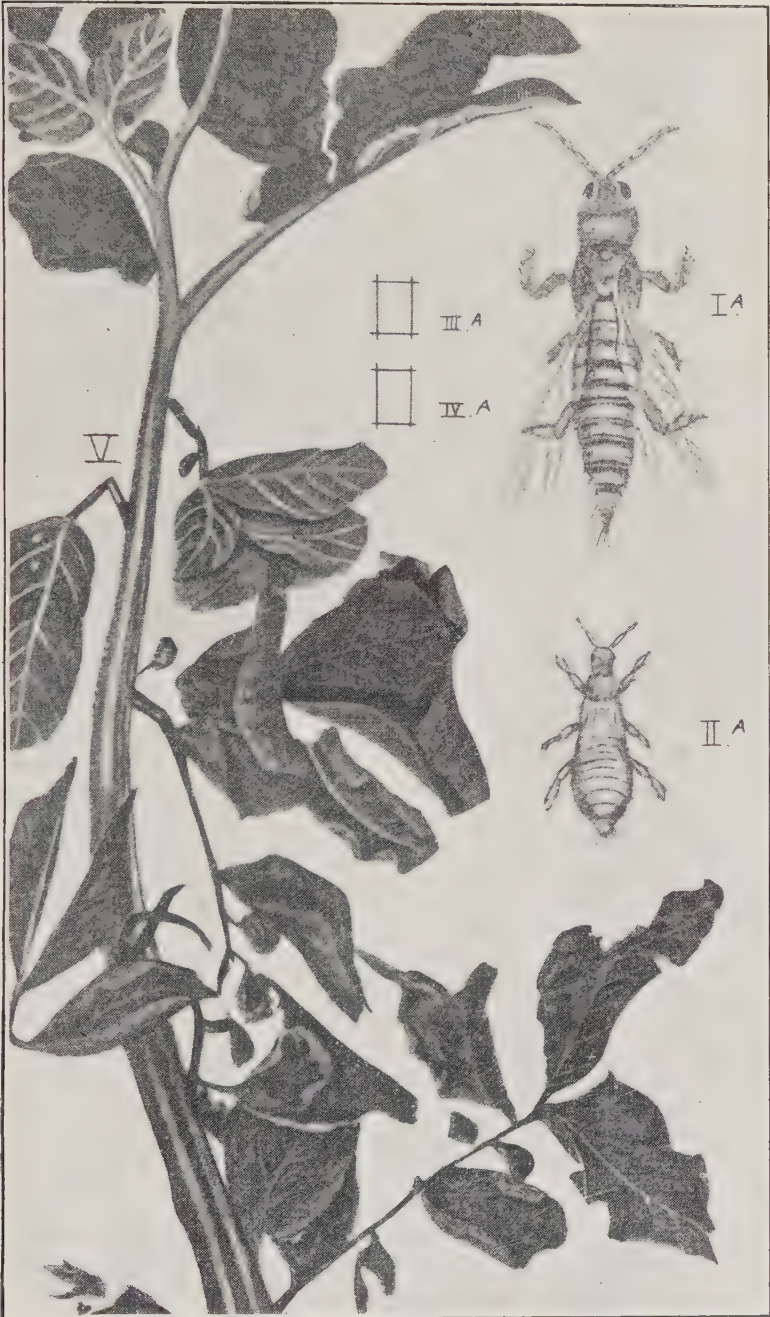
All *débris*, such as dried potato plants, weeds, &c., on potato fields should be gathered up and burnt. By this means the hibernating insects and their eggs will be destroyed.

During 1910, Mr. G. Seymour, Potato Expert, and the writer carried out some experiments at Romsey against thrips. A Strawsonizer spraying outfit was used. This was fixed in a dray and worked very satisfactorily, the spray being forced up under the leaves so that the plants received a good soaking. Tobacco water was used with good results. This wash requires careful straining, otherwise it is liable to choke the nozzles of the pump, and that would leave many plants unsprayed. The formula for tobacco wash is as follows:—Steep 1 lb. of tobacco in 1 gallon of hot water, and allow it to soak for 24 hours; boil 1 lb. of soap in 1 gallon of water until the soap is dissolved; strain the tobacco water into the soap water; stir well, and make up to 5 or 6 gallons. Use waste stems of tobacco.

Benzole emulsion, a cheap preparation, costing about 4d. per lb. wholesale, has proved very effective. One lb. makes 5 or 6 gallons of spray, and every insect reached by this mixture is killed at once. Now that many motor spray pumps are on the market, the work of spraying can be done thoroughly and in a short space of time.

Hellebore or a weak kerosene emulsion, has also given good results as a spray fluid. In America the use of lime in the following proportions has been highly recommended:—35 lbs. of lime to 100 gallons of water. In other cases, a stronger spray using from 50 to 75 lbs. of lime to 100 gallons of water was used with the best results.





1. POTATO THRIP. (*Thrips tabaci*, Lindemann.)

EXPLANATION OF PLATE.

Fig.

I.A. Female. Perfect insect. Magnified.

II.A. Perfect insect. Magnified.

III.A. Perfect insect. Natural size.

IV.A. Larva. Natural size.

V. Potato stem, with foliage dying. Natural size.

The potato thrips and its control have been the subject of experiments conducted in America by Mr. Dudley Moulton. The results are detailed in Bulletin 80, published by the United States Department of Agriculture. Thrips which attack other kinds of plants and trees may be combated by the same remedy which he gives for the potato thrips. From an extensive series of trials of various kinds of spray fluid, Mr. Moulton comes to the conclusion that, though tobacco leaf extract, one part to 50 of water, is very successful, yet a more penetrating and hence more effective material is got by making up the tobacco leaf extract with an oil instead of with water only. The oil spray is forced more easily than the water spray into the buds, and penetrates more readily the oily covering of the insects themselves. The oil spray recommended is composed of:—Distillate oil emulsion,  $1\frac{1}{2}$  to 2 per cent. solution; black leaf-tobacco extract, 1 part to 60 parts of water. The distillate oil emulsion is prepared as follows:—Hot water, 12 gallons; white oil or fish oil soap, 30 lbs.; distillate oil (23 degrees, Baume), 20 gallons. The soap is dissolved in a kettleful of boiling water, and poured into the spray tank; the oil is then added, and the mixture is agitated violently, and sprayed under a pressure of 125 to 150 lbs. into other barrels. This stock solution is diluted before use with 24 gallons of water to each gallon of solution.

As a deterrent against thrips, spraying with coal-tar water has been recommended. The formula is as follows:—Boil 1 lb. of coal tar in 2 gallons of water, and, while hot, add from 50 to 100 gallons of water.

Several of the accompanying illustrations have been reproduced from *The Destructive Insects of Victoria*, by C. French, F.L.S., F.E.S.

#### CUT WORMS AND LOOPER CATERPILLARS.

These include a number of different but closely allied species variously known as Cut Worm Caterpillars, Looper Caterpillars, Army Worms, Take-all Grubs, &c.

Plate No. 2 shows some of the common cut worm moths, also two other species of closely allied Noctuids (night moths). In the Museum of Economic Entomology and Ornithology of this Department are specimens of all the Victorian Cut-worm moths, their eggs, and larvæ. The collection may be inspected by all interested.

Of those shown in the plates, the Silvery Moth (*Plusia argentifera*) is at times destructive to potato crops in many parts of Victoria. Complaints from growers have also been received regarding the *Agrotis* (several species), Potato Looper Moth (*Plusia verticillata*), *Heliothis armigera*, *Leucania* sp., and others. The cut worms are the larvæ of these insects, and every year they are the cause of much destruction on farms, vineyards, and gardens. Wheat, oats, barley, maize, vines, plums, tomatoes, onions, beans, cabbages, and potatoes are all subject to attack.

#### LIFE HISTORY.

Closely allied as they are in their habits of life, differences between individual members of this group are chiefly morphological. There are at least two broods of cut worms in a season, but further observations will be necessary before the number is finally ascertained. The moths usually fly about at dusk, and deposit their eggs on any suitable plant. The eggs hatch in a few days, and the young cut worms begin to feed at once, any kind of green food being greedily eaten by them.

The cut worms vary in colour according to the species. Those of the Tomato Moth vary from green to yellowish, but most of the *Agrotis* are of a dirty greyish or light-brown colour, without hairs or spines, smooth, and greasy looking, often being of a similar colour to the ground in which they hibernate. Some of the cut worms feed both day and night; others rest during the day just under the soil, or under logs, stones, bark, bags, and rubbish, and feed only during night.

The young are fully grown in a couple of weeks, and are then ready to pupate. The pupa is of a dirty reddish-brown colour, sometimes almost black. After pupating, they remain in the ground from ten to fifteen days during warm weather before the moths emerge; in cold weather the period is much longer.

#### REMEDIES.

By the eradication of weeds and the burning of haulms and stems of harvested crops the cut worm evil may be greatly minimized, as by this means many eggs are destroyed.

Growing crops may be treated in the following manner:—Place between rows of an infested crop or at short distances apart, bundles of any succulent weed or vegetable which has been previously poisoned by dipping it into a strong mixture of Paris green, 1 oz. to a bucket of water. The cut worms eat the poisoned plants, bury themselves and die. In hot dry weather the bundles should be put out after sundown. Correspondents have frequently inquired whether there is any likelihood of vegetables absorbing Paris green from bundles when placed near the roots. I am assured by the Chemist for Agriculture that there is no danger, as Paris green is practically insoluble, and therefore cannot be absorbed by plants.



## 2. CUT WORM MOTHS.

## EXPLANATION OF PLATE.

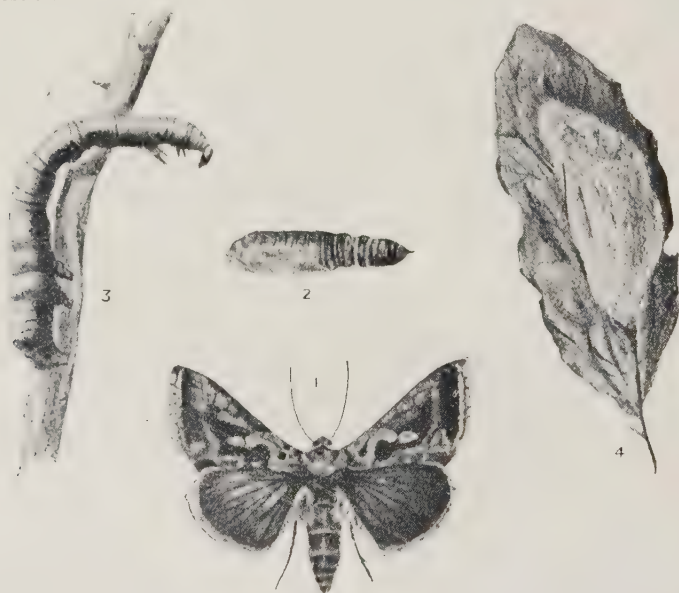
- Fig.  
 I. *Chloridea obsoleta*. (Tomato Moth.)  
 II. *Cirphis unipuncta*.  
 III. *Euxoa radians*.  
 IV. *Persectania evengi*. (Climbing Cut Worm.)  
 V. *Plusia argentifera*. (Silvery Moth.)

- Fig.  
 VI. *Agrotis spina*. (Bugong Moth.)  
 VII. *Euplexia nigririma*.  
 VIII. Larva of *Agrotis*.  
 IX. Larva curled up.  
 X. Pupa of *Agrotis*.

(Natural size.)



The poisoned bran mash has also been successfully tried, especially against the Silvery Moth, the larvæ of which are so destructive to potato crops. In preparing the mash use one part, by weight, of arsenic, one of sugar, and six of bran, add sufficient water to make a wet mash. The mixture is usually made in a wash tub or half barrel. This is filled three-fourths full with dry bran, and there is added about 5 lbs. of arsenic, which is thoroughly stirred through the bran with a spade or shovel; 5 lbs. of sugar are next placed into a pail, water is added, and the sugar stirred until it is dissolved. The sugar water is then added to the bran and arsenic, and the whole well stirred. More water is added, and the stirring continued until every portion of the mash becomes thoroughly saturated. The mixture should be placed around and through the crop, or at the foot of the tree, plant, or shrub infested, dropping it in the shade when this can be done. Both of these preparations should be kept out of the way of children and domestic animals.



3. POTATO LOOPER MOTH (*Plusia verticillata*) (after W. W. Froggatt).

1. Adult Moth. 2. Pupa. 3. Larva. 4. Cocoon.

With regard to the efficacy of the poisoned bran mash, I have recently received the following letter from Mr. G. Ray, of Lindenow, Gippsland:—

The cut worms were very prevalent this season, but I have had great success in destroying them. I had a crop of English barley, and, thanks to the use of the bran mash, I have just thrashed from 40 to 70 bushels per acre. The caterpillars were two or more inches deep in shady places, and I am sure that I would not have had any returns unless precautions had been taken.

Mr. C. W. Malley, Eastern Province Entomologist in South Africa, reports excellent results with poisoned baits. He says:—

It occurred to me that by cutting up all available green stuff (lucerne, barley, forage, rape, young succulent weeds, &c.) into small bits, say half-an-inch in length, it could be moistened with the poisoned sweet and then scattered broadcast over the lands with least labour and material. In this way it is distributed evenly, and at such frequent intervals, that the cut worms are practically certain to find it before they do the plants. Their fondness for sweets induces them to fully engorge themselves with the bait, a fact which makes their destruction certain. There is also no danger to stock, for the pieces of bait are so small that nothing but poultry can pick them up, and it is not likely that even they will get enough to injure them. But, as a precaution, they should be kept from the lands where bait has been spread.

During the past six months several additional experimental tests have been made with cut worms, and with satisfactory results. I see no special difficulty in the way of applying the following remedy on a large scale to lands planted with tobacco, maize, or other crops, and therefore call attention to it for the benefit of any who may have occasion to use it:—

*Method of Preparation.*

Arsenate of soda	..	..	..	1 lb.
Treacle or brown sugar	..	..	..	8 lbs.
Water	..	..	..	10 gals.

Dissolve the arsenate of soda and the treacle in the water. In the meantime cut up lucerne, or other green stuff into small bits, and then moisten it with the poisoned



4. ICHNEUMONS.

(Dark winged Ichneumon.) Beneficial Insects. Destroyers of Potato Insect Pests.

EXPLANATION OF PLATE.

Fig.

I. and II. *Rhyssa semipunctata*, Male and Female.

III. *Pimpla intricatoria*. (Spotted black Ichneumon.)

(Natural size.)

Fig.

IV. *Ophion* sp.

V. *Ophion* sp.

sweet. Be careful not to make it too wet, or it will not scatter well when broadcasting. For the best results, the bait should be distributed a few days after the ground has been ploughed, and all green succulent vegetation destroyed. The cut worms that are not injured in ploughing will then be on the surface again, and on account of their long fast, practically all of them will be prowling about in search of food. In this way, one application will probably be sufficient. If injury is noticed after the young maize plants appear, the application should be repeated.

Where a spray is employed in place of poisoned bait, arsenate of lead has proved one of the best. By using this spray growers in the Frankston and Cheltenham districts have saved their potato crops from the ravages of the Silvery Moth. Where cut worms are feeding in grass paddocks adjoining crops, it is advisable to spray a strip of the crop. After devouring the grass they move on to the crop, and, when they come to the sprayed portion, devour it greedily, and are soon destroyed. If vegetables are sprayed it is advisable to thoroughly wash them before using.

The trench system is a simple and effective method of eradication. A trench or furrow should be either ploughed or dug around the crop towards which the cut worms are feeding. It must have clear cut sides; those nearest the crop should be undercut so as to prevent the cut worms from crawling out of the trench. Deep holes should be made in the trench at intervals of, say, 5 yards. When travelling towards the crop the cut worms fall into and crawl along the trench and ultimately into the holes. A few shovelfuls of earth, well rammed, will then speedily destroy them. Should the pest be already in the crop, it may be useful to run a few furrows through it to prevent it spreading.

Another plan that answers well is to place a flock of sheep in the infested paddock adjoining the grass crop. The constant walking about of the sheep will destroy many cut worms.

If cut worms are prevalent in gardens, rake the ground up close to the plants. By this means many of them are turned up, and if poultry are allowed to run over the ground, very few will escape their notice. They are also easily injured by the rake, and are then likely to be eaten by ants and insectivorous birds when exposed on the surface of the ground.

Numbers of cut worms are destroyed by hymenopterous and other parasites. Very wet and cold weather also keeps them in check.

## POTATO MOTH.

(*Lita solanella*, Boisd.)

According to various writers this destructive pest of the potato crop has been known in Australia since 1854, and has spread to all the States. It has caused considerable losses to growers, and is certainly the worst potato pest in the Commonwealth.

Potato moths are usually more plentiful after a mild warm winter. There are two broods of moths. The first, the winter brood, may destroy the young plants and thereby ruin the crop. The moths of the second brood deposit their eggs on the potatoes themselves when the tubers are stored or are in the field. Occasionally, especially if potatoes are grown in stiff soil, the moths will crawl down the cracks in the ground and deposit their eggs on the tubers. The eggs are usually from 20 to 30 in number, and hatch in from six to ten days. In sandy soil tubers are rarely so attacked. The young grubs, when hatched, usually feed upon the eyes of the potatoes; they then tunnel towards the centre of the tubers, causing them to become brownish black, and inducing decay. Sometimes when the potato plants are fully grown the female moth deposits her eggs on the leaves. The young grubs feed on these, and afterwards gnaw their way down the main stalks, reaching the tubers below. Fortunately for growers the chrysalids of the potato moth are attacked by parasites, bacterial diseases, and climatic influences, which destroy great numbers.

## LIFE HISTORY.

*Eggs*.—Very minute, of a white colour and glistening.

*Caterpillar*.—When fully grown it measures about  $\frac{1}{2}$  inch long, and is of a faint pinkish colour, with a brown head. It usually pupates under the skin of the potato, and is surrounded or protected by dirt, excrement, &c.

*Chrysalid*.—The pupa or chrysalid is dark brown in colour, and is enclosed in a silken bag or cocoon.

*Moth*.—The moth is small, of a light brownish-grey colour, the size being:—body, about  $\frac{1}{2}$  inch in length; front wings, which are darker than the hind ones, female, about  $\frac{1}{2}$  inch across when expanded, male slightly smaller. The wings of both sexes are feathery or fringed, but this is not so pronounced in the male as in the female.

## PREVENTION AND REMEDIES.

Dead potato plants, discarded and small potatoes, and rubbish should be gathered and burnt. Old sacks and cases in which there have been infected potatoes should be dipped into boiling water. By this means any grubs and chrysalids secreted in them will be destroyed.

5. POTATO MOTH (*Lita solanella*, Boisd.)

## EXPLANATION OF PLATE.

- Fig.  
 I. Moth. Magnified.  
 1A. Moth. Natural size.  
 II. Pupa. Magnified.  
 III. Head and first three segments of larva.  
     Upper side. Magnified.  
 IIIA. Head and first three segments of larva.  
     Under side. Magnified.

- Fig.  
 IV. Potato sliced to show effects of attack by  
     larvæ of moth. Natural size.  
 V. Larva. Natural size.  
 VI. Foreleg. Moth.  
 VII. Hing leg. Moth.



Seed infested with the grubs should never be planted, nor should ground where moth-affected potatoes were grown the previous year be used again for potatoes. Plant the seed deeply, and keep it well covered. The ground should be pressed firmly down, and it is advisable to till it a second time. Never leave potatoes exposed in the field. When they are dug up they should be at once bagged and removed to the storeroom, where they must be placed in bins, pits, or any other places where moths cannot get at them to lay their eggs in the eyes of the tubers. It is a common practice with many growers to simply heap the potatoes up in the storeroom without any covering, and to leave the doors wide open. It is no wonder that considerable losses occur.

Trapping by means of lamps is of use in destroying the moths, which fly about at night. Procure an ordinary tin basin, and in this place a brick and enough kerosene to reach half way up the brick, and on the brick a lighted lamp. The moths are attracted to the light, and, flying against the lamp, fall into the kerosene, which kills them. The basin could be placed on an ordinary box, such as a kerosene case. Several of these lamps could be placed in a field of potatoes at night time.

When the moths commence to make their appearance, it is advisable to spray the crop with some arsenical spray, such as arsenate of lead. This will destroy the young grubs as soon as they commence to feed. A good arsenical spray is prepared as follows:—Boil 1 lb. of white arsenic and 2 lbs. carbonate of soda (crystals) in  $\frac{1}{2}$  gallon of water for twenty minutes. Separately dissolve 7 lbs. of arsenate of lead in 1 gallon of warm water. When both mixtures are cold mix them together. Bottle into twelve 1-pint bottles, and use one bottle to 30 gallons of water. Mix the chemicals in wooden buckets.

As many reliable brands of arsenate of lead are now on the market, and at a fairly cheap rate, the majority of growers may prefer to purchase the ready-made article instead of going to the trouble of mixing this excellent spray mixture themselves.

In cases where spraying is expected, spaces might be left between every few rows of potatoes for the horse drawing the spray pump to pass, otherwise many of the plants will be trampled down. During a recent spraying demonstration on potatoes, this oversight on the part of the growers was very noticeable. At the present time some excellent motor, automatic, and other spray pumps, specially designed for potato spraying, are on the market, the nozzles being made so that the whole plant may be thoroughly sprayed. Six or more rows of potatoes can be sprayed at the same time. Recent experiments by the writer and other officers of the Department proved the value of these pumps, which are now coming into general use.

As the potato moth is proclaimed an insect pest under the Vegetation Diseases Act, it would be advisable that the potato inspectors should inspect all storerooms in the country districts, where potatoes are grown, and see that every precaution is taken by growers to protect the tubers from the ravages of this moth. One careless grower in a district can breed enough moths to ruin all his neighbours' crops, and it is against such a grower that action should be taken.

## POTATO AND TOMATO WEEVIL.

(*Desiantha nociva*, Lea.)

This is a comparatively new pest of the potato, and was first reported in December, 1908, from the Essendon district. Here it caused young potato and tomato plants to fall to the ground by eating the stems through at the base. It has now been found in many parts of Victoria, extending right into the Wimmera district. Like many other native insects it has forsaken its natural food, probably some of the native Solanums, and taken to potatoes and tomatoes. Various vegetables and garden plants are also attacked by it.

The larva is of a light pea-green colour, and measures about a quarter of an inch in length. In the daytime it is usually found in the soil a few inches below the surface. When about to pupate it constructs a cocoon made of soil, where it remains for a couple of months until it emerges as the perfect beetle.

The beetle, which measures about a quarter of an inch in length, and varies in colour from light grey to dark brown. Some specimens have a V-shaped mark on the wing cases, and two projections, one on each side of the wing cases. It is quite as destructive as the larva, and, like it, goes down into the soil in the daytime, and comes up to feed at night. The larvæ often feed in the daytime as well as at night, but the perfect insects rarely do so. It is a prolific breeder, and every possible means should be adopted to prevent its spread. It may be seen at all times throughout the year, and the damage done is considerable.

## PREVENTION AND REMEDIES.

All weeds, especially marshmallows, on land adjoining potato crops should be destroyed. This insect will eat almost any kind of weed, so it is necessary that these precautions be taken. Fortunately, in the arsenate of lead spray we have an excellent remedy for this pest. Experiments carried out by this Branch prove that by this means it can be kept in check.

6. POTATO AND TOMATO WEEVIL. (*Desiantha nociva*, Lea.)

## EXPLANATION OF PLATE.

Fig.

- I. Perfect insect. Natural size.
- II. Perfect insect. Natural size. Side view.
- III. Perfect insect. Enlarged.
- IV. Perfect insect. Enlarged. Side view.
- V. Larva. Enlarged.
- VI. Larva. Enlarged. Side view.

Fig.

- VII. Larva. Natural size. Side view.
- VIII. Larva. Natural size. Side view.
- IX. Pupa. Enlarged.
- X. Pupa in cocoon. Natural size.
- XI. Cocoon. Natural size.

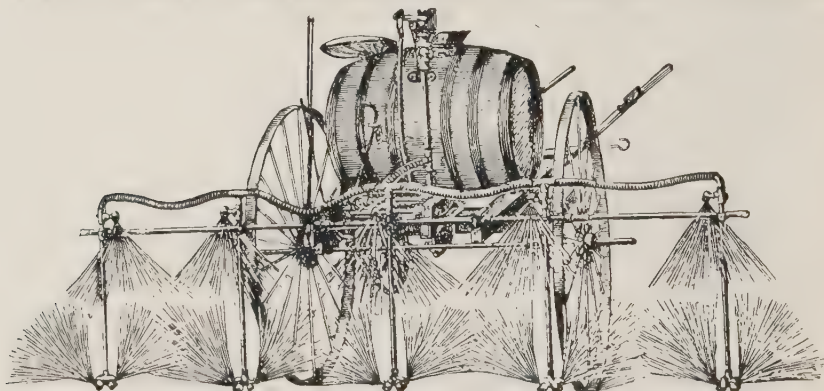


### JASSIDS, LEAFHOPPERS OR FROGHOPPERS.

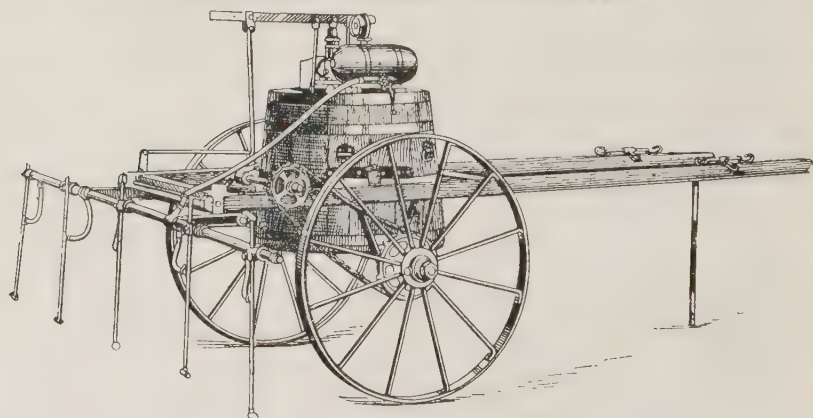
These are small greenish-yellow insects, not unlike miniature cicadas, and about the size of the aphides on roses. They are very active, and can be seen in thousands on the leaves of all kinds of plants, now and again doing damage to the young shoots and foliage. Large numbers are often seen on potato plants.

These insects do not seem to cause any noticeable damage, but, as they appear to be on the increase, it would be as well for growers to keep a strict watch for them. If found causing any damage it would be necessary to spray the crop with Benzole emulsion, 1 to 5 gallons of water.

### 7. TYPES OF SPRAY PUMPS IN GENERAL USE FOR SPRAYING POTATO CROPS.



THE "FLEMING" AUTOMATIC POTATO SPRAYER.



IMPROVED AUTOMATIC "DONCASTER" SPRAYER.

### THE RUTHERGLEN BUG.

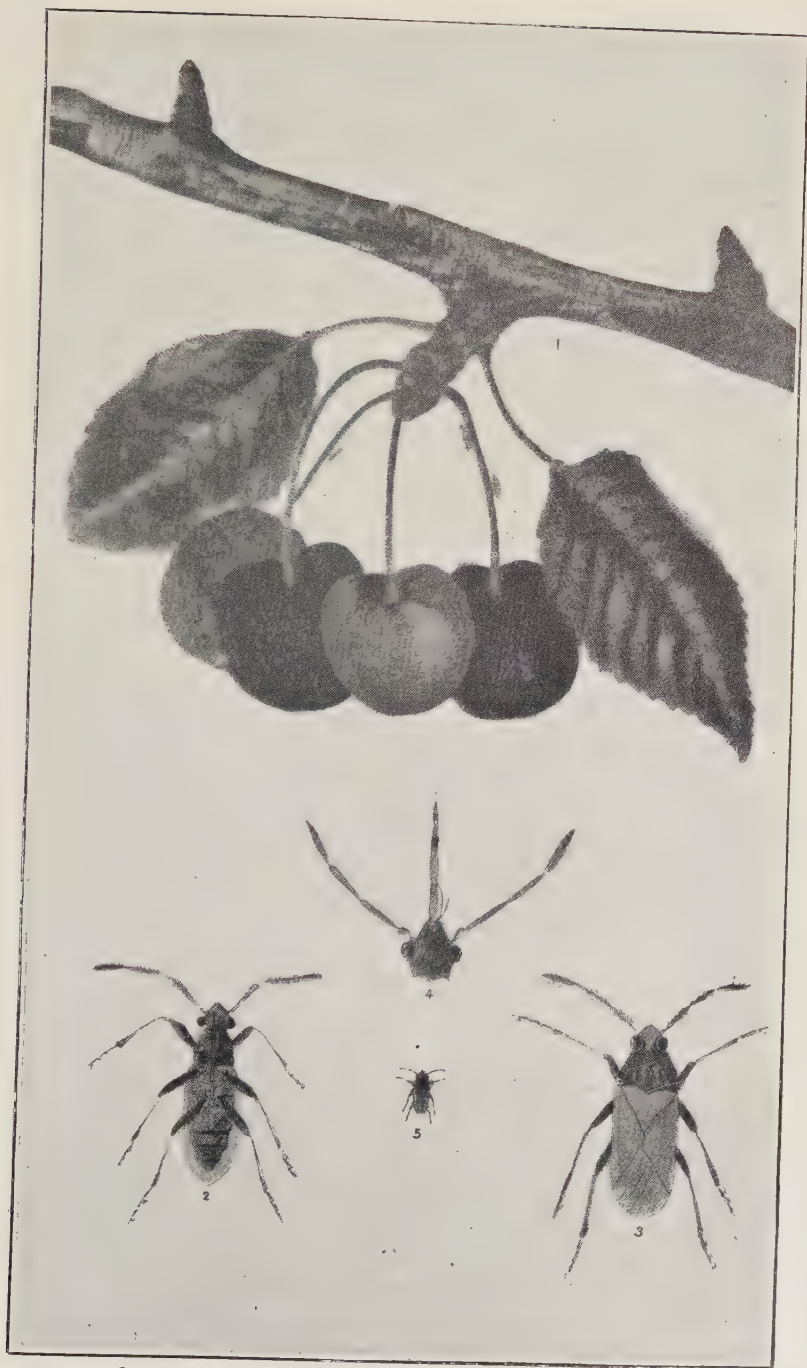
(*Nysius vinitor*.)

This is one of the many plant bugs found in Victoria, and it is probably the most destructive. The perfect insects measure about  $1\frac{1}{2}$  lines in length, the general colour being greyish to light brown; the wings, with the exception of a few dark line-like markings when closed, are transparent. It is a very active insect, and has a habit of dropping or flying to the ground when plants, fruits, &c., on which it is resting are touched. The bug is furnished with a rostrum or beak, with which it sucks the sap from the plants, and causes them to wither and die. In the summer it is seen actually in thousands on potato and other crops, garden plants, &c., thereby causing growers considerable loss.

Some years ago, the first specimens of this insect were sent in from Rutherglen, hence the name Rutherglen bug. At that time, the insects were doing much damage to vegetables, tomatoes, potatoes, and to all kinds of fruit. Various experiments were carried out by Mr. C. French, Senior, for the suppression of the pest, and good results were obtained by using the Benzole emulsion spray. At that time no motor spray pumps were available, and spraying the potato crops with hand pumps was a tedious proceeding.

### PREVENTION AND REMEDIES.

See treatment recommended for thrips.



8. RUTHERGLEN BUG. (*Nysius vinitor*.) After C. French.

EXPLANATION OF PLATE.

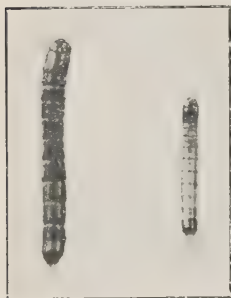
- Fig. I. Branch of cherry tree, with fruit and insects.  
 II. Perfect insect. Under view. Magnified.  
 III. Perfect insect. Upper view. Magnified.  
 IV. Head of adult insect. Magnified.  
 V. Perfect insect. Natural size.

**WIRE WORMS.**

There are a considerable number of species of wire worms found in Victoria. They belong to the family of *Elateridæ*. The mature insects are known as Skip Jack, Click, or Flip Beetles, from their peculiar habit of springing into the air with a click, should they fall on their back.

The wire worm, which is of a dark-brown shining colour, varies from  $\frac{1}{4}$  to nearly 1 inch in length, being usually about as thick as a match. The body is cylindrical, rather flat, compressed at the head and pointed behind; each of the first, second, and third segments of the thorax carries a pair of short legs. Wire worms have powerful mandibles or jaws, which are well adapted for biting roots. The mature insects vary in length from  $\frac{1}{2}$  to  $1\frac{1}{2}$  inches, the colour being generally dark brown or approaching light black.

Fortunately for growers in Victoria this pest does not appear to make much headway, no doubt owing to its natural enemies. A bad outbreak occurred some years ago in the Ballarat district, and caused growers much concern, but the trouble has not recurred. The accompanying photographs show how the larvæ of these beetles destroy the potatoes.



9. WIRE WORMS.  
(Natural size.)



10. POTATOES DAMAGED BY WIRE WORMS.

**PREVENTION AND REMEDIES.**

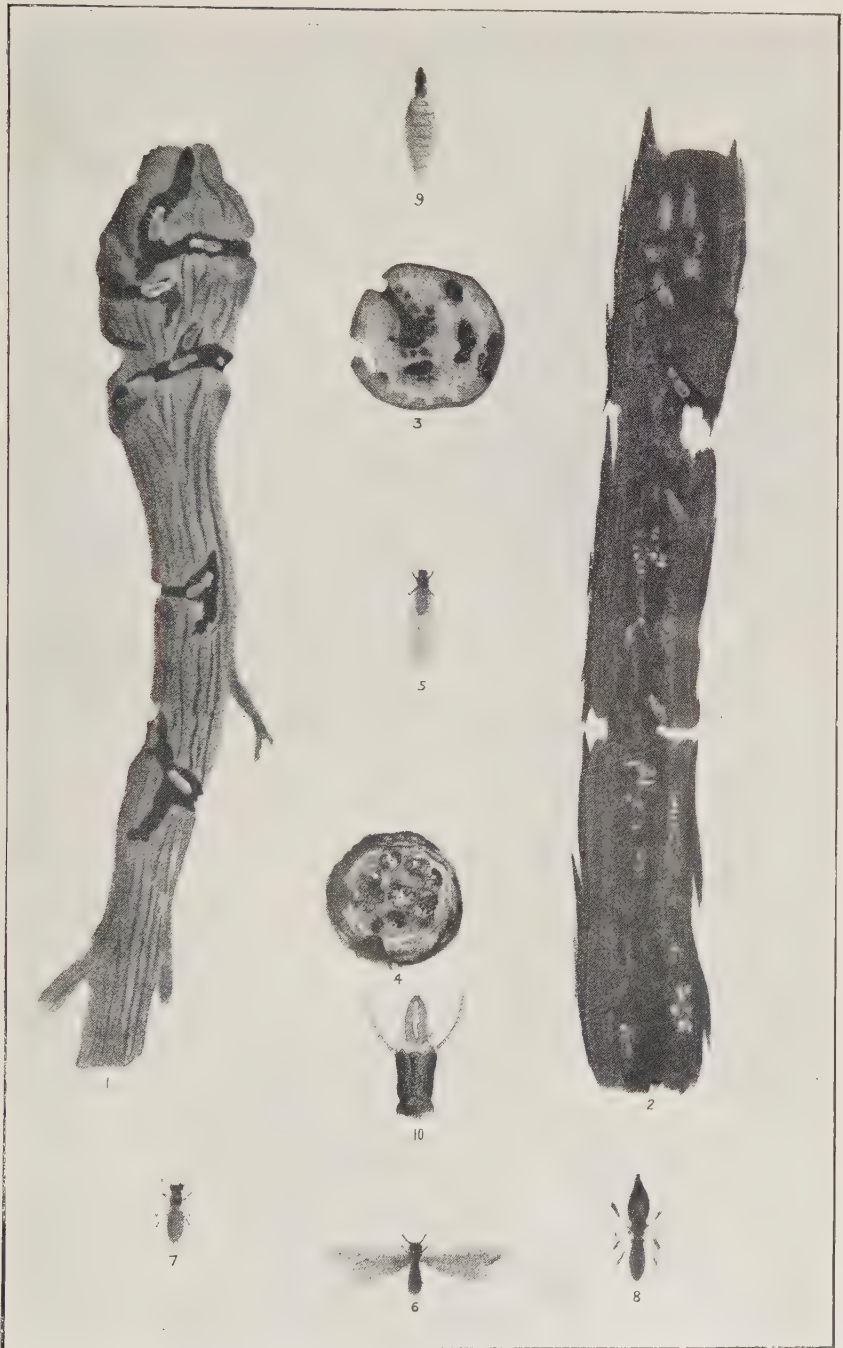
One of the best methods of keeping wire worms under control is to cultivate the ground frequently and thoroughly, turning it over and exposing the insects so that insectivorous birds can clear them off. Frequent harrowing will also keep them down, as by this means the wire worms are injured, and never reach the beetle stage. Poisoned baits are sometimes used with good results. These are made by cutting a few turnips, carrots, or potatoes into small pieces, soaking them in arsenate of lead, and then putting them into the soil.

Vaporite is a useful remedy. (For treatment and quantity to use, see under Victorian White Ant.)

**THE VICTORIAN WHITE ANT.**

(*Termes lucidis*, Froggatt.)

The so-called White Ant, which has no affinity to the true ant, is exceptionally common in many parts of this State, and its depredations are unfortunately well known. It is a destroyer of timber and furniture, as well as apricot, plum, and other fruit trees, vines, potatoes, &c. When a fruit tree is badly attacked by white ants the bark tends to change colour, and assume a sickly appearance.

11. VICTORIAN WHITE ANT. (*Termes lactis*, Froggatt.)

## EXPLANATION OF PLATE.

- Fig.
- I. Portion of orange root attacked by white ants, showing insects at work and damage done. Natural size.
- II. Portion of vine stem attacked by white ants, showing insects at work and damage done. Natural size.
- III. Transverse section of orange root destroyed by white ants. Natural size.
- IV. Transverse section of vine root showing damage done by white ants. Natural size.
- V. Male, with wings folded. Natural size.
- VI. Male, with wings extended. Natural size.
- VII. Worker. Natural size.
- VIII. Soldier. Natural size.
- IX. Queen. Natural size.
- X. Head of "Soldier White Ant," showing the powerful jaws. Magnified.



Fortunately for potato growers this pest does not seem to make much headway, but at the same time it should be watched, for when once our native insects leave their natural food there is no telling what damage they may do. The white ants are small and of a yellowish-white colour, and in general appearance, not unlike true ants. They inhabit structures known as termitaria, which are mounds or hillocks, in old roots of eucalyptus and other trees. The plate gives a good idea of the various phases of the white ant and its workings.



12. POTATOES SHOWING DAMAGE CAUSED BY WHITE ANTS.

#### PREVENTION AND REMEDIES.

When it is intended to form a potato field, the first thing to be done is to have all old stumps and roots of trees removed and burnt. I have seen in many fields numbers of old stumps and roots of trees left, and on examination found them to be full of white ants in all stages. Where they are allowed to harbor they are liable to attack potatoes, so the necessity of destroying their breeding places is obvious. A careful grower has very little to fear from the attacks of white ants if this precaution is taken.

When taking out old stumps many white ants are likely to fall into the holes caused by their removal, and in such cases it is advisable to pour a cupful of bisulphide of carbon into each hole; cover it immediately, and stamp the soil well down. The fumes of the poison will destroy the ants. When using this chemical great care must be taken that no lights are placed near it as it is highly inflammable.

Another plan is to dig Vaporite into the soil, which is then pressed firmly down. The quantity to be used varies with the character of the soil; light soils require a lesser amount than heavy ones. The lighter the soil the more easily is the mixing effected, and the more easily will the gas penetrate. The quantity of Vaporite used is generally at the rate of 225 lbs. per acre for light soils, and about 350 lbs. for heavy soils, but for filling holes these quantities should be exceeded.

#### MILLIPEDES.

Millipedes are closely allied to insects, but belong to another class (*Myriapoda*, which includes centipedes). The body is crustaceous, the antennæ or feelers seven-jointed,



13. MILLIPEDES.

#### EXPLANATION OF PLATE.

- Fig.  
I. Millipede. Magnified.  
II. Natural size of No. 7.  
III. Millipede. Magnified.  
IV. Natural size of No. 5.

- Fig.  
V. Millipede. Magnified.  
VI. Antenna or horn of Millipede. Magnified.  
VII. Millipede. Magnified. (After Ormerod.)

and the first segment of the body has the form of a little shield. The feet are numerous.

The eggs are laid in the ground amongst vegetation, &c. The young *Julidæ* (Millipedes) live two years before they are perfect, during which time they grow and change their skin five times. They maintain the same appearance throughout, excepting for an increase in the number of legs.

Millipedes are both herbivorous and carnivorous in their habits. At times they attack young potato plants when just sprouting under the soil, and on that account are mentioned here. In some localities in this State they do a certain amount of damage to other crops as well as potatoes.

#### PREVENTION AND REMEDIES.

One of the best remedies is to thoroughly cultivate the land. Remove and destroy all rubbish under which they could shelter. When they are in the ground Vaporite has given good results. The Vaporite should be well incorporated with the soil to a sufficient depth when the ground is cultivated. (See further particulars as to quantity to use under Victorian White Ant.)

Mr. W. E. Collinge, M.Sc., Birmingham, in his *First Report on Economic Biology*, states that the following remedy has proved very successful. In flower beds, dig out a hole sufficiently large to contain the fist and wrist; fill with bran, and cover with water. After two or three days pour on to the bran boiling water. The contents of two such holes were examined after treatment, and were found to contain 2,448 and 1,793 dead millipedes respectively.

#### WOOD LICE, SLATERS, OR SOW BUGS.

This pest is destructive to potatoes, both in the field and when stored in pits. Wood lice are not, strictly speaking, insects, but as they cause considerable damage they are included in this article on potato insect pests.

Wood Lice belong to the *Crustaceæ*, a prime division of *Arthropods*, which includes lobsters, crabs, shrimps, prawns, &c. The common wood louse is mostly nocturnal in its habits, retiring during the day under stones, *débris*, old bags, bark, and, in fact, almost any kind of hiding place that is accessible, and coming forth in the evening to feed. It has a peculiar habit of contracting itself into a ball when disturbed. The eggs are very small, shining, and pale yellow-white in colour; they hatch rapidly under suitable conditions.

#### PREVENTION AND REMEDIES.

Do not allow any *débris*, old bags, logs, &c., to lie about on fields where it is intended to plant potatoes, as the animals may lodge there.

*Traps*.—Cook in a solution of arsenic a piece of parsnip, beetroot, or potato, and place it in the haunts of the wood lice. They will eat this greedily.

Mr. A. M. Lea says—

They can be trapped in large numbers by placing empty boxes (or bones on top of old sacks) at the side of the garden, and into these the wood lice will creep on the approach of day.

Should the wood lice be in the ground it would be advisable to treat the soil with Vaporite before sowing. Recent experiments conducted by the writer with this material proved very satisfactory. The Vaporite was well worked into the soil amongst the wood lice, and after a few days an examination of the ground showed the wood lice to be quite black, the gas from the Vaporite having destroyed them.





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In this Map the customary shades of blue to represent different degrees of rainfall have not been used, but striking colours are employed to show the grower at a glance the average rainfall of any particular district.

